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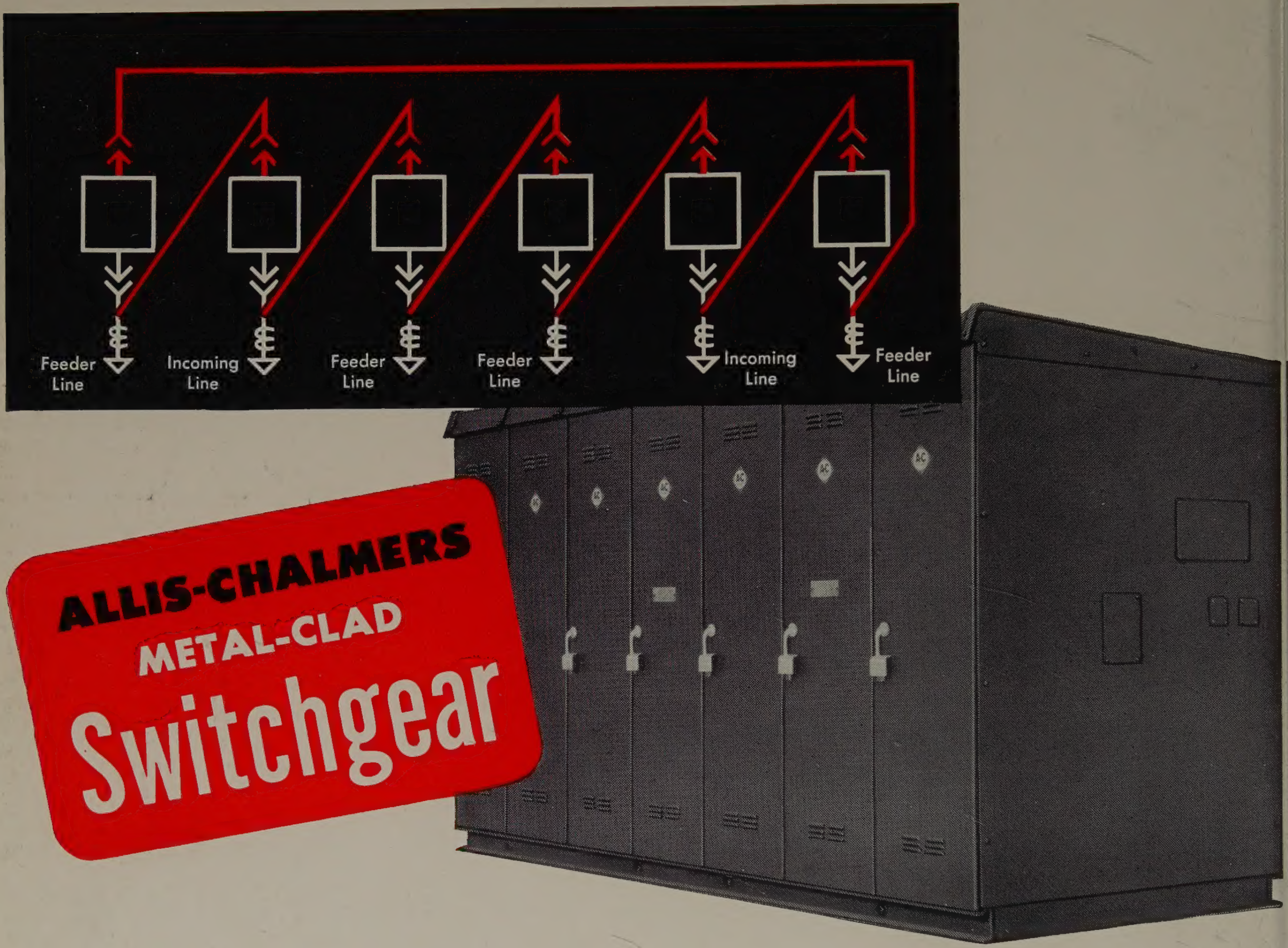

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The Cover: A receiver-antenna unit being hoisted up a test tower used in the Bell System for path testing of microwave radio routes. These tests are described in the article on pages 571–7.

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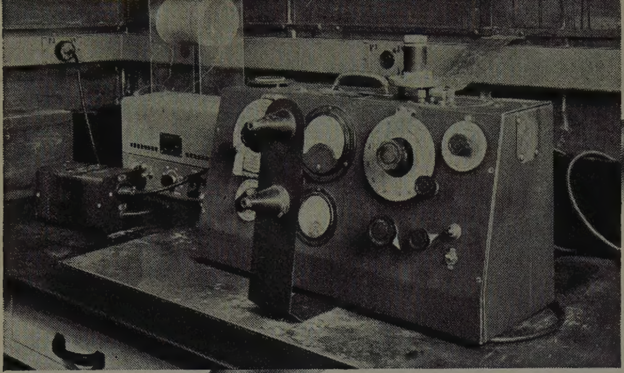

Testing Insulation Resistance

Compare the electrical properties of

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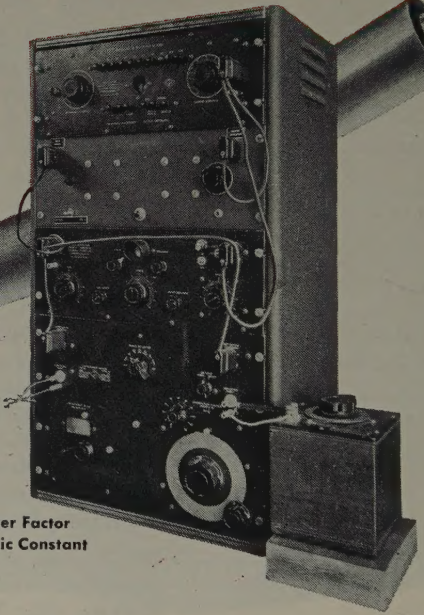

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HIGHLIGHTS........

AIEE Meetings. As this issue goes to press, the annual Summer General Meeting gets underway in Atlantic City, N. J. A complete report of the meeting's activities will appear in August. A number of the authors who will present conference papers at the meeting have agreed to supply copies of their papers to those requesting them. A list of papers available to date has been announced (*pages 642, 644–5*). The next General meeting of the Institute will be the Pacific General Meeting in Vancouver, Canada, in September (*page 642*).

Path Testing for Microwave Radio Routes. To avoid undesirable radio propagation conditions, and use the least number of intermediate stations practicable and the smallest towers which will provide satisfactory radio transmission, propagation tests on paths proposed for backbone radio relay routes has become usual practice in the Bell system. The test equipment and procedures are described, and the results obtained in typical cases analyzed (*pages 571–7*).

Lamme Medal. The Lamme Medal for 1952 was presented during ceremonies at the Summer General Meeting to I. F. Kinnard of the General Electric Company for his contribution in design and developments in instrumentation and measurements. The history of the medal, a description of the medalist's career, and Mr. Kinnard's acceptance address are included in this issue (*pages 578–83*).

Options in Engineering Education. In recent years, the appearance of new fields within electrical engineering has witnessed a subsequent decline in popularity of the power field with engineering students. One of the contributing factors is the lack of creative instruction and modern facilities in the power curriculum (*pages 595–7*).

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The Magnetic Amplifier. Although many excellent papers have been written about this subject for the specialist, very little information is available for the engineer seeking a general knowledge of the magnetic amplifier. This is the first of a series of three articles designed to fill this need; the others will appear in subsequent issues (*pages 583–8*).

Phase System of Magnetic Recording for EDVAC Drum Memory. After presenting a formulation of an EDVAC number word and describing pulse magnetic recording methods in general, the component circuitry, method of recording, and the general over-all system of the EDVAC computer's magnetic drum memory are described (*pages 590–5*).

Capacitively Coupled Field Mapper for 2-Dimensional Distributed Source Fields. Current problems in torsional stress analysis, heat transfer, viscous fluid flow, eddy currents, and electric and magnetic fields often involve Poissonian or distributed source fields. As mathematical solution of these fields has not been possible except in special cases, analogues have been developed for 2-dimensional fields. The electric analogue described can give directly usable 2-dimensional solutions of high accuracy (*pages 600–05*).

Low-Frequency Self-Generated Oscillations in the D-C Carbon Arc. The experimental apparatus is described, and the experimental results discussed in terms of the oscillations in voltage, current, light, and sound. The mechanism and theoretical explanation of quiet oscillations are presented, and the results of the research summarized (*pages 612–16*).

Sensitive Direct-Writing Plethysmograph. This thoroughly tested instrument is portable and compact. It can be standardized accurately and adapted to already-existing galvanometers such as standard electrocardiographic machines. It can determine whether disease of the arteries is present and assist in clarifying many common symptoms of the extremities. The specifications for a satisfactory plethysmograph receive special attention (*pages 619–23*).

Fast-Response High-Current Thyratron Power Supplies for Inductive Loads. The constantly increasing need to cut the response time of inductive loads has caused the modern high-current gas thyratron tube to assume great importance due to its power capabilities. These tubes do not introduce any appreciable additional time constant into the system when they are used as amplifiers. Various ways of energizing such loads are discussed. One of these is the half-wave circuit with an optimum value of capacitance in parallel with the load; this offers the fastest response for the equipment required (*pages 627–30*).

Bimonthly Publications

The bimonthly publications, *Communication and Electronics*, *Applications and Industry*, and *Power Apparatus and Systems*, contain the formally reviewed and approved numbered papers (exclusive of ACO's) presented at General and District meetings. The publications are on an annual subscription basis. In consideration of payment of dues, members (exclusive of Student members) may receive one of the three publications; additional publications are offered to members at an annual subscription price of $2.50 each. The publications also are available to Student members at the annual subscription rate of $2.50 each. Nonmembers may subscribe on an advance annual subscription basis of $5.00 each (plus 50 cents for foreign postage payable in advance in New York exchange). Single copies, when available, are $1.00 each. Discounts are allowed to libraries, publishers, and subscription agencies.

New Adjustable Inverse CO Relay. This new version of an old relay achieves improved accuracy, adjustability of the characteristic current-time curves, and both simplification and other improvements in the mechanical design (*pages 607–09*).

Antiswing Crane With Anticreep Variable-Speed Hoisting. To eliminate the necessity of riggers steadying loads of hazardous materials being transported by a crane, servomechanism techniques have been applied to the drives of a laboratory model. The two systems accomplishing this end are described (*pages 635–7*).

Correction. In the power-circuit diagram, Figure 1, of the digest, "Electronic Frequency Changer," by Harold Winograd (*EE, May '53, p 398*), the "excitation anode" was incorrectly labelled "excitron anode."

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

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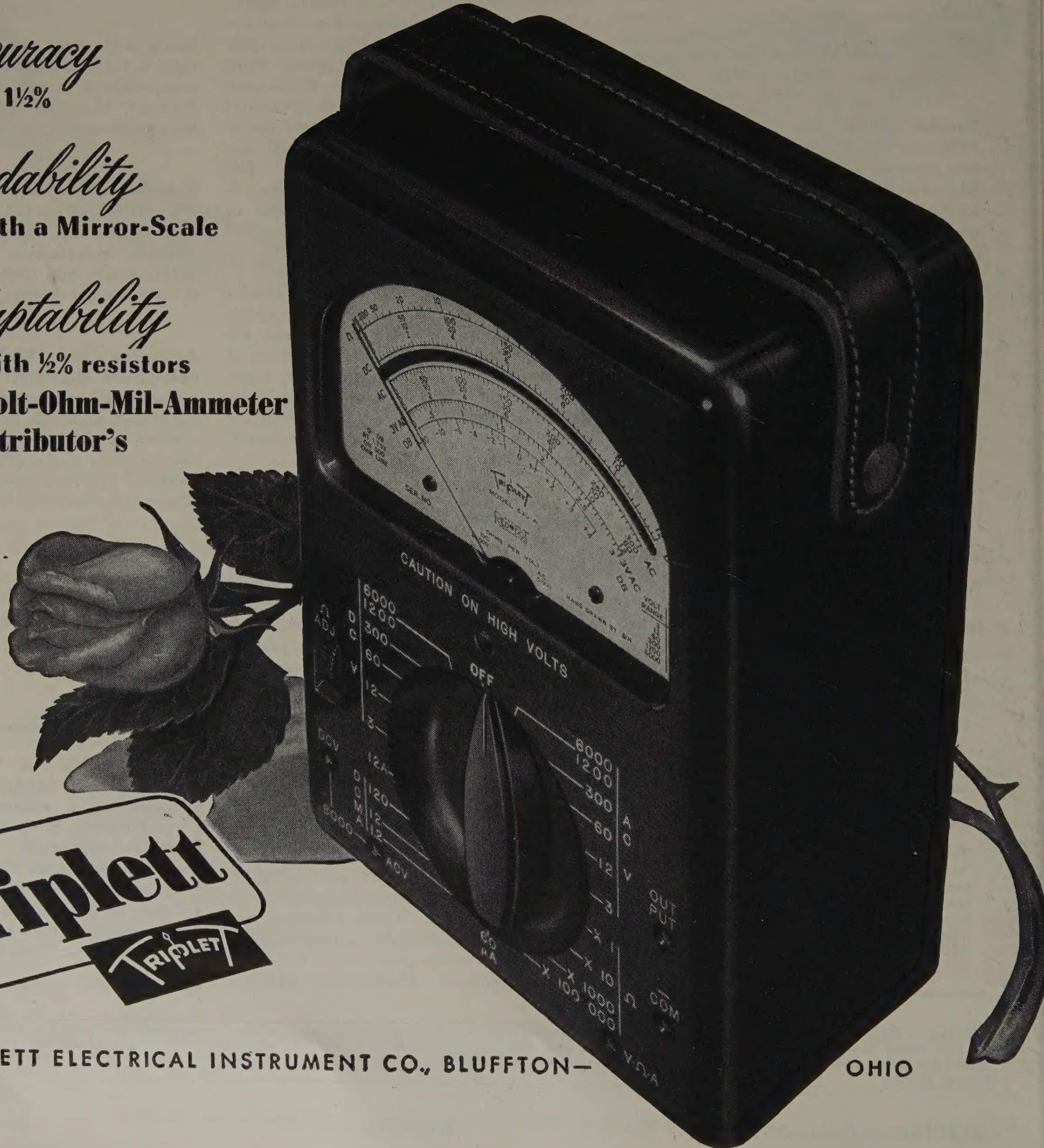

Path Testing for Microwave Radio Routes

R. D. CAMPBELL
MEMBER AIEE

The equipment and procedures used for path testing for microwave radio routes are described and the methods of analyzing the results obtained in typical cases are given in some detail.

IN PLANNING THE construction of a microwave radio relay system, it is important that sites for the stations be so selected that undesirable radio propagation conditions are avoided. It also is desirable to minimize the number of intermediate stations required and to utilize the smallest towers which will give satisfactory radio transmission.

While contour maps and visual sighting methods are of great assistance in selecting station sites, the maps are sometimes inaccurate; they do not indicate obstructions such as high trees and buildings, and atmospheric conditions are often not good enough for visual sighting. Furthermore, in most cases this information will not indicate clearly the possibilities of strong ground reflections which may adversely affect transmission. For these reasons, it is the usual practice in the Bell System to make propagation tests on paths proposed for backbone radio relay routes.

THEORETICAL CONSIDERATIONS

THE TESTS USUALLY MADE to check path propagation conditions consist in transmitting microwave energy between antennas at the ends of the path elevated to various heights up to 200 feet above the earth. The purpose of these tests can be understood best by considering an idealized situation such as that indicated in Figure 1 where *ARB* represents, in greatly exaggerated form, the surface of the earth along the desired path. For this case the earth is assumed to be perfectly smooth and to have a reflection coefficient approaching unity. With the antennas at *A* and *B* located at ground level, the direct path is obstructed by the earth and the radio energy is attenuated below the value calculated for free space transmission over the same length path.

As the antennas are raised, the attenuation caused by the earth decreases until the signal strength reaches a value equal to that corresponding to transmission in free space. Theory and tests indicate that the free space value is reached when the antenna elevations are such that the minimum clearance of the direct path above the earth is about 0.6 of the first Fresnel Zone radius as represented by line *CD* on Figure 1. For antenna elevations below the line-of-sight path, only the small percentage of the energy which is diffracted beyond the horizon will reach the receiver. For all antenna elevations above the path barely grazing the earth's surface there will be a reflected ray reaching the receiver in addition to the direct ray; under the assumption of an earth with unity reflection coefficient, the reflected and direct rays will have equal strength.

With the antennas elevated above *CD* by an amount such that the length of the path traveled by the reflected ray *ERF* is between 1/6 and 5/6 wavelength longer than the direct ray, the reflected wave will tend to reinforce the direct wave and signal strengths above calculated free space values will be observed. The maximum received signal is 6 decibels above free space and occurs at elevations such that the clearance of the direct path over the earth is equal to the radius of the first Fresnel Zone. With this clearance, the path of the reflected ray is 1/2 wavelength longer than the path of the direct ray and the two waves add since there is a 180-degree phase shift on reflection. As the antennas are raised still higher the reflection path length will increase so that the reflected wave will arrive in such phase as to reduce the signal received over the direct path. When the reflected path is 1 wavelength longer than the direct path, the two signals will just cancel each other. This condition occurs when the clearance of the direct path above the earth equals the radius of the second Fresnel Zone. As the antennas are raised still further the received signal strength again increases passing through another maximum 6 decibels above free space (clearance equal to radius of third Fresnel Zone) and falls again to zero (clearance equal to radius of fourth Fresnel Zone). This waxing and waning of the signal strength is repeated over and over as the antennas are raised, the maximum signals corresponding to clearances above earth equal to the radii of the odd-numbered Fresnel Zones and the minimum signals corresponding to clearances equal to the radii of the even-numbered Fresnel Zones.

The dashed lines on Figure 2 illustrate the afore-described theoretical considerations and show the calculated deviation from free space transmission of signals received over smooth or plane earth as a function of the path clearance. Calculations based on a path assuming a reflection coefficient of zero and a knife-edge obstruction or discontinuity on the

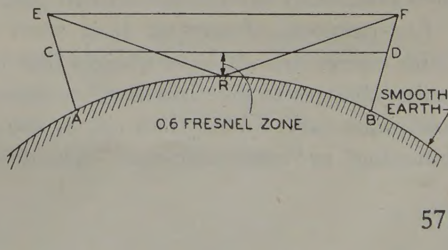

Figure 1. Diagram showing direct and reflected rays, with the vertical scale greatly exaggerated

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Revised text of paper **53-191**, "Path Testing for Microwave Radio Routes," recommended by the AIEE Committee on Radio Communications Systems and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Southern District Meeting, Louisville, Ky., April 22–24, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

R. D. Campbell is with American Telephone and Telegraph Company, New York, N. Y.

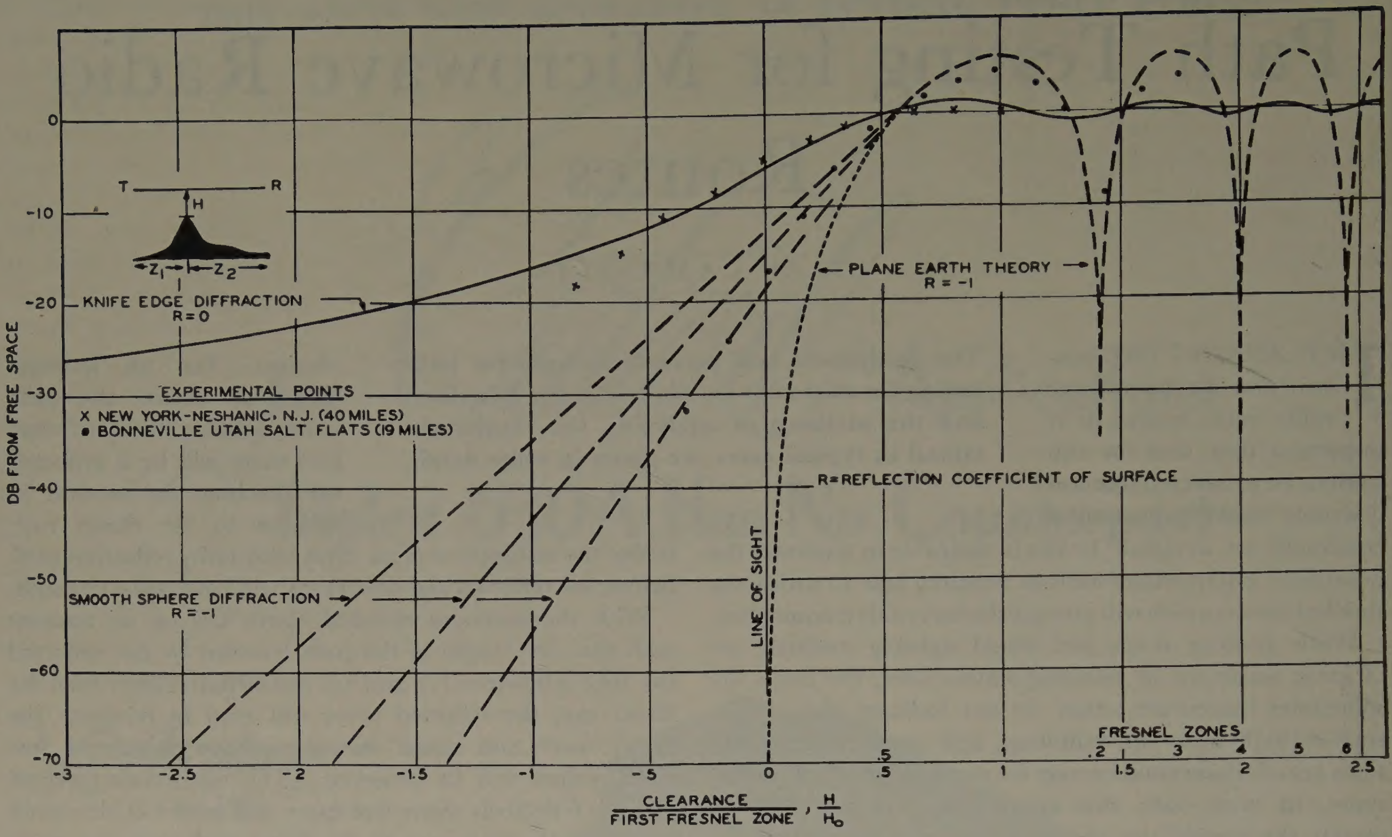


Figure 2. Effect of clearance on radio transmission

earth's surface such as that illustrated by the insert on Figure 2 show that for this case the received signal remains within a decibel or two of that for free space transmission for clearances over the obstruction greater than about 0.3 of a Fresnel Zone (see solid curve on Figure 2).

As indicated by the points plotted on Figure 2, actual paths having characteristics approaching the smooth earth calculations and the calculations for knife-edge obstruction have been encountered. In general, however, actual paths can be expected to have characteristics lying somewhere between the theoretical cases assumed.

Another factor which complicates the problem of selecting suitable antenna locations is the fact that propagation conditions are affected by the dielectric constant of the atmosphere which in turn is a function of atmospheric pressure, temperature, and humidity. The radio energy travels along a straight line between the transmitter and receiver when the dielectric constant is the same at all elevations. When the dielectric constant increases with height, the radio waves are refracted upward and the path clearance of the energy that reaches the receiving antenna is less than the clearance for straight-line transmission. Conversely, when the dielectric constant decreases with height, the radio waves are refracted downward and the path clearance of the energy that reaches the receiving antenna is greater than that for straight-line transmission. Both conditions are encountered in practice.

For purposes of analysis it is often assumed that the radio energy travels in a straight line but that the earth radius changes to give increased or decreased clearance as conditions vary. This gives rise to the concept of "earth flattening" or "earth bulging." The degree of "flattening" or "bulging" is frequently expressed in terms of the ratio between the effective earth radius and the actual earth radius as, for instance, an earth of 4/3 or 2/3 actual radius.

It has not been possible to determine accurately what range of effective earth radii may be encountered in a given area but estimates based on the rather meager information available indicate that the changes follow the laws of probability varying around a mean value of about 4/3 radius with extreme conditions represented by "flat earth" (infinite radius) on the one hand and 2/3 earth radius on the other hand being reached only a few per cent of the time during the worst months. Accordingly it is customary to use 4/3 earth radius as "normal" and to investigate clearances and ground reflections under the extreme conditions of flat earth and 2/3 earth.

Since the afore-described changes in the transmitting medium have the effect of causing the effective clearance on any path to increase and decrease with time, its effect on transmission over the theoretical path assumed in Figure 1 is to cause the characteristic curves of Figure 2 to shift to the right or left along the abscissa as transmitting conditions change. Care must be taken, therefore, to pick antenna heights so as to avoid, in so far as possible, operation in the nulls caused by cancellation of the direct by the reflected signals as the transmission characteristic shifts. In the majority of cases reflections occur from several surfaces and the aim is to choose such antenna heights that the nulls from the various surfaces will not coincide as conditions change. Where strong ground reflections can not be avoided, as sometimes happens on paths over water or over salt flats, it is considered good practice to select antenna elevations which fall, if possible, on a broad hump of the characteristic between nulls. Elevations providing a minimum clearance of about 0.25 first Fresnel Zone radius for the 2/3 earth radius condition to 1.7 for the flat earth condition are considered about optimum for such paths.

It will be apparent from the foregoing discussion that path tests should be made, if possible, under normal atmospheric conditions, or transmitting conditions which are likely to prevail most of the time. Such conditions generally exist during the daylight hours when the atmosphere is most likely to be stable. In any event it is undesirable to make tests during periods when strong fading is observed as this in itself would be an indication of varying propagation conditions. The prevailing conditions are checked by observations on one or more obstacles in the path whose locations are definitely known.

EQUIPMENT ARRANGEMENTS

Special microwave equipment has been designed for radio path testing in the Bell System. A block diagram of this equipment is shown in Figure 3. It operates on frequencies in the range 3,800–4,200 megacycles. The transmitter, Figure 4, includes a reflex klystron oscillator arranged for continuous wave operation with a power output of about 200 milliwatts. The receiver consists of a crystal converter, local microwave oscillator, intermediate-frequency amplifiers, attenuator, second detector, and output meter. The radio-frequency portions of the transmitting and receiving equipments are mounted on a carriage assembly directly behind 57-inch parabolic antennas as illustrated in Figure 5. The antenna carriage assembly is equipped with rollers to facilitate raising and lowering along the side legs of 200-foot portable aluminum towers used for path testing. The antenna and associated radio equipment can be oriented either in azimuth or elevation by means of remotely controlled motors. The power supply equipment, controls, measuring equipment, and, in the case of the receiving terminal, the main intermediate-frequency amplifier are at the foot of the tower and connected to the radio-frequency equipment by flexible cables.

The test towers are fabricated of round aluminum-alloy members built up in sections 8 feet long and 22 inches square. These sections are fitted together with aligning pins which make it possible to stack them one above the other, a maximum of 25 sections comprising a tower 200 feet high. A special erecting frame is provided which makes it possible to assemble the entire tower at ground level, successive sections being added at the bottom after raising the assembled portion by means of the erecting frame. Guys and winches are used to hold the tower vertical. A receiver-antenna unit being hoisted up the test tower is shown on the cover.

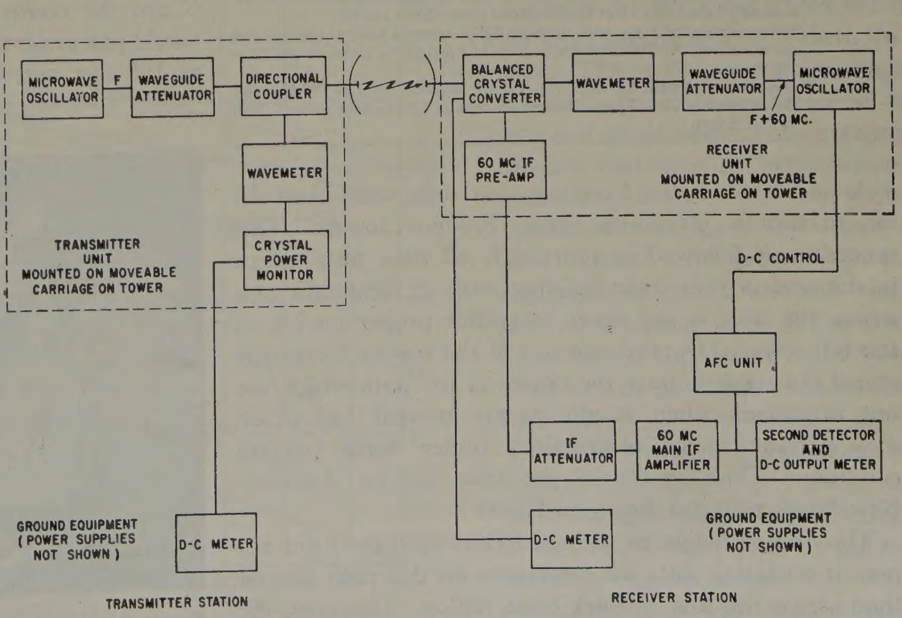


Figure 3. Block diagram of equipment for path testing

Calibration of the equipment is carried out by measuring the energy at the output end of the transmitter waveguide with the antenna feed horn disconnected on a portable relative power and frequency meter. This measurement is correlated with the reading of the transmitter output meter. The portable power and frequency meter is then used to check the receiver sensitivity by measurement of the power supplied from a local signal generator adjusted to the test frequency and introduced through a calibrated attentuator into the antenna end of the receiver waveguide. The power is measured with the *IF* attenuator in the receiver adjusted to give reference reading on the signal level meter. The path loss when receiving from the distant transmitter then can be determined from the calibration measurements and the *IF* attenuator setting at the receiver required for reference reading on the signal level meter, proper allowance being made for the antenna gains, losses introduced by cable connections and directional couplers in the test equipment.

The receiving and transmitting equipments for path testing weigh approximately 2 tons each. The majority of this weight is contributed by the tower, erecting frame, anchors, guys, and winches. The equipment for either station occupies about 1,000 cubic feet and two medium-sized trucks and trailers are used to transport it. In addition, since the equipment must be operated at remote locations, portable emergency engine-driven generators must be used for power supply. Communication between the transmitting and receiving stations is usually obtained by the use of very-high-frequency portable radio sets.

TESTS ON ACTUAL PATHS

Two sections of the second New York–Philadelphia–Washington *TD-2* radio relay route have been selected for the purpose of describing in detail the results of path-testing measurements. Figure 6 is a map showing the location of the two sections under consideration, namely the section from New York (American Telephone and Telegraph Company, Long Lines Building, 32 Avenue of

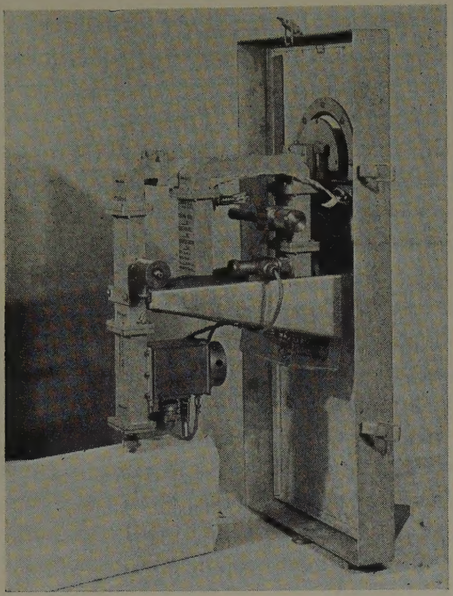


Figure 4. Microwave transmitter for path testing

the Americas) to a point near Red Bank, N. J., referred to as the Atlantic repeater station and the section from Atlantic to New Egypt, N. J., about 13 miles east of Bordentown, N. J.

Path From Atlantic to New Egypt. The Atlantic–New Egypt path, 23.6 miles long, was selected as typical of farming country with some hills, a type of terrain which is frequently encountered in the East in establishing intercity systems. A profile of the surface of the earth based on a 4/3 earth radius for this path is shown in Figure 7. The ordinates show feet above mean sea level at New Egypt and Atlantic, and the abscissas miles from New Egypt. Three series of test measurements were made over this path transmitting from New Egypt on 4,130 megacycles; and receiving at Atlantic as described below:

Test	Description of Test
A.......	Measurements of path loss with the antennas at both ends elevated simultaneously in steps of 5 feet above ground from 100 to 195 feet.
B.......	Measurements of path loss with the New Egypt antenna fixed at 195 feet and the antenna at Atlantic elevated in steps of 5 feet above ground from 75 to 195 feet.
C.......	Measurements of path loss with the Atlantic antenna fixed at 195 feet and the antenna at New Egypt elevated in steps of 5 feet above ground from 40 to 195 feet.

As indicated in the foregoing, test data were obtained for maximum elevations using 200-foot towers. This procedure is followed in practically all such tests except in the case of tests from building roofs or mountain tops where the area is too small to permit proper guying of the full tower. Data at the top of the towers frequently reveal obstructions near the center of the path which are not important when conditions are normal but which may become major obstructions under earth bulging conditions. The results of the tests on the Atlantic–New Egypt path are shown on Figure 8.

The limited height of the test towers (200 feet) did not permit obtaining data for clearances on this path greater than about the first Fresnel Zone radius. However, the fact that the maximum signal strength observed was only about 1 decibel above free space indicates the absence of strong ground reflections on the path under normal conditions and subsequent studies did not reveal any likelihood of serious reflections under earth bulging conditions. The general slope of curves *B* and *C* in the range just below free space loss is of interest. The fact that the path loss decreases more rapidly with equal changes of antenna heights for curve *B* than for curve *C* is an indication that the controlling path obstruction for antenna elevations greater than 110 feet or so is nearer Atlantic than New Egypt (probably due to trees on hills *F* or *G*, Figure 7).

From Test A, Figure 8, it is determined that the transmission loss is the same as the free space loss when the antennas at both ends are elevated 182 feet above ground. A straight line *A* has been drawn on Figure 7 to show the center line of the transmission path with both ends at this elevation. As indicated in the discussion under the section on theoretical considerations, this indicates that the minimum path clearance with the antennas at this elevation is approximately 0.6 Fresnel Zone.

From Test B, Figure 8, it is seen that the crossover with free space transmission occurs with the receiver at Atlantic elevated 182 feet and the transmitter at New Egypt elevated 195 feet. A line *B* interconnecting these points has also been drawn on Figure 7.

Finally from Test C, Figure 8, it is seen that the crossover with free space transmission occurs with the transmitter at New Egypt at 145 feet and the receiver at Atlantic at 195 feet. A straight line *C* interconnecting these points also has been plotted on Figure 7.

By inspection of Figure 7 it appears that the minimum clearance for path *C* occurs above point *D*. By plotting the 0.6 Fresnel Zone line corresponding to path *C* it is found that its clearance over *D* is 33 feet and over *E* is 45 feet as represented by the dotted arrows. Also a portion of the 0.6 Fresnel Zone line corresponding to path *A* has been plotted and this line clears the earth at points *F* and *G* by about 45 feet (dotted arrows). Now if trees on hill *G* are the controlling obstruction the transmission path would just graze the tree tops with the New Egypt antenna at 195 feet and the Atlantic antenna at 118 feet above ground (see line *H* on Figure 7). From curve *B* on Figure 8 it is determined that the received field with the antenna 118 feet above ground at Atlantic is only 8 decibels below free space and this appears unusually low. However, if trees on hill *F* are controlling, the grazing path would occur with the antenna at Atlantic 106 feet above ground (see line *J* on Figure 7). From curve *B* on Figure 8 the received field with the Atlantic antenna at 106 feet is found to be 10 decibels below free space which appears

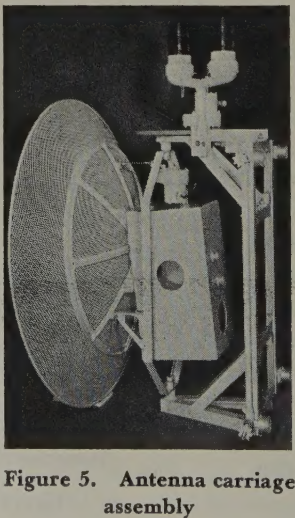
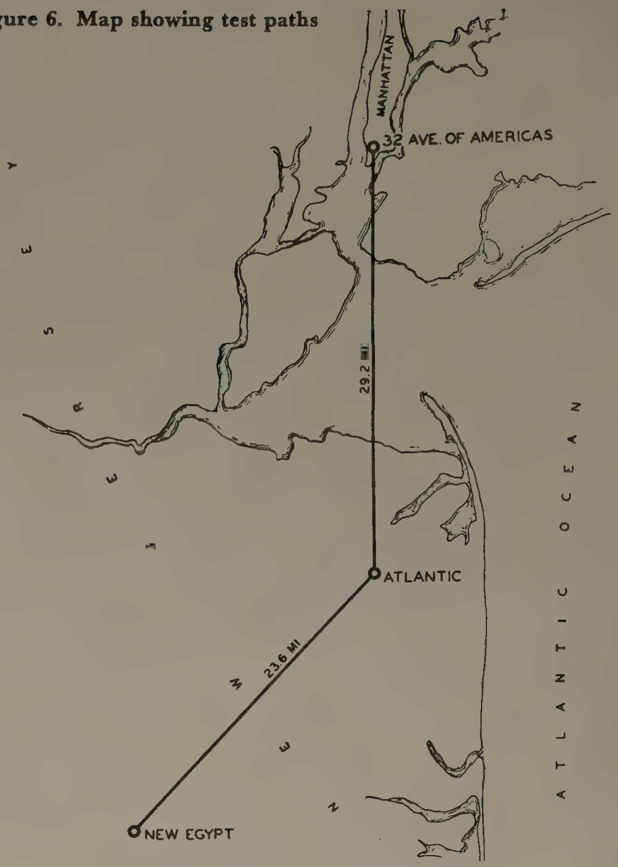


Figure 5. Antenna carriage assembly

reasonable. The controlling obstruction therefore appears to be trees about 45 feet tall on hill *F*. Similar analysis of the data on hills *D* and *E* indicates that there are probably no trees or other obstacles on these hills.

In order to determine the antenna heights required, it is necessary to take into account the reduced clearances which may be experienced under extreme atmospheric conditions represented by an effective 2/3 earth radius. For this purpose a 2/3 smooth earth contour has been plotted on Figure 7. The separation between the contours measured along the ordinate at any point indicates the amount by which the clearance of the transmission path will be reduced when the conditions change from an effective earth radius of 4/3 to 2/3. Under the 2/3 earth condition, therefore, the tree tops at point *F* and the hill top at *D* would be pushed up from the arrow heads over these points to the points marked *x*. If tower heights were selected so that the center line of the transmission path just cleared the highest of these points the path would be just grazing under conditions of an effective earth radius of 2/3. Since the path loss at grazing clearance is seldom less than 10 or 12 decibels below free space transmission, additional clearance is usually added to reduce this loss to about 4 decibels for an effective earth radius of 2/3. In this example an additional clearance of 1/3 first Fresnel Zone radius has been added as indicated by the circles above the *x* points. A straight line passing through these circles would indicate tower heights of about 120 feet at New Egypt and 250 feet at Atlantic. However, tests of the adjacent section of route south of New Egypt indicated a requirement for an antenna elevation of 243 feet at New Egypt and in order to keep the tower at Atlantic as low as practicable it was decided to locate all the New Egypt antennas at the 243-foot level (237½-foot tower). By drawing line *D* from this point to just clear the uppermost circle in the path (over point *F*), the elevation required for the antenna at Atlantic is found to be 206 feet (200-foot tower).

Figure 6. Map showing test paths



Path From New York to Atlantic. The path from New York to Atlantic was selected for consideration here because of the overwater transmission involved. This path is 29.2 miles long, located as shown on Figure 6. Figure 9 is a profile of the earth's surface on the southern portion of this path plotted in feet above mean sea level, assuming a 4/3 earth radius. The profile of the buildings on Manhattan was not prepared as tests and visual sighting observations indicate that they are probably not controlling factors on this path. Incidentally this path was selected after considerable study and testing involving various antenna locations on the Long Lines Building at 32 Avenue of the Americas in New York as well as various locations in New Jersey.

For safety reasons it was necessary to limit the height of the test tower on the Long Lines Building to only 64 feet and the test involving raising antennas simultaneously at both ends of the path was omitted since no significant data could be obtained

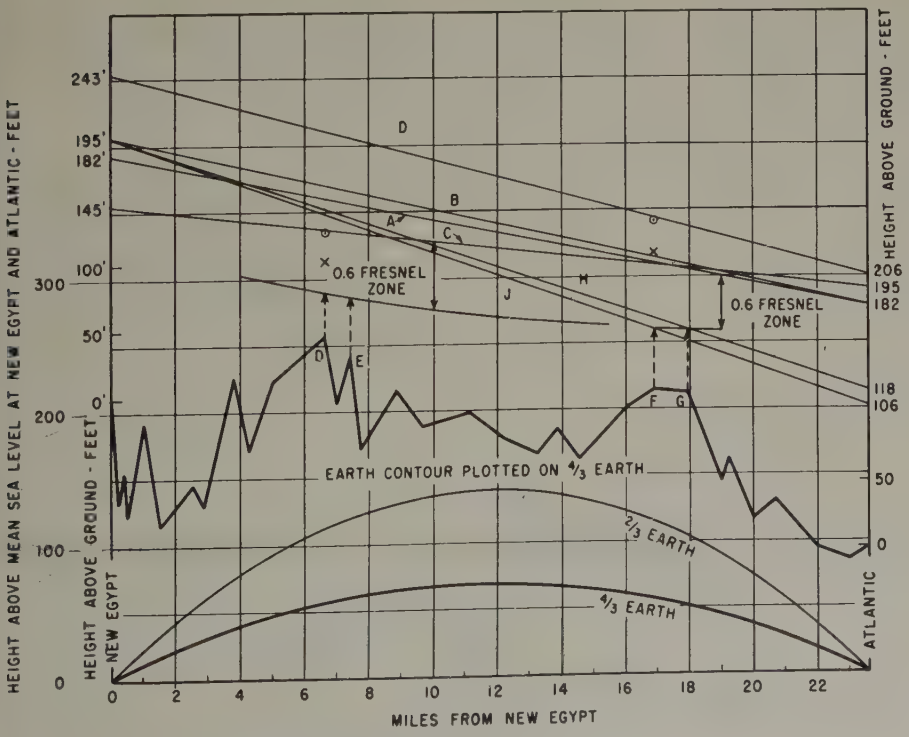


Figure 7. Analysis of tests on New Egypt–Atlantic path, 23.6 miles long

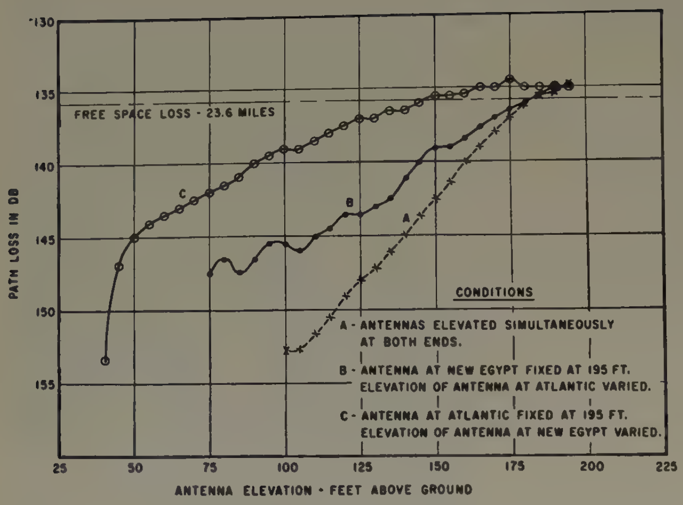


Figure 8. Test results for Atlantic–New Egypt path, with the transmitter at New Egypt and the receiver at Atlantic

from such tests with the limited antenna height at New York. Test data were obtained on this path as follows:

Test	Description of Test
B-8	Measurement of path loss with the transmitting antenna at New York fixed at 60 feet above the tower base and the receiver at Atlantic elevated in steps of 5 feet above ground.
B-9	Measurement of path loss with the transmitting antenna at New York fixed at 15 feet above the tower base (on 28th floor of building) and the receiver at Atlantic elevated in steps of 5 feet above ground.
C-3	Measurement of path loss with the receiving antenna at Atlantic fixed at 195 feet and the transmitting antenna at New York elevated in steps of 5 feet from 10 to 60 feet above the roof.
C-4	Measurement of path loss with the receiving antenna at Atlantic fixed at 120 feet and the transmitting antenna at New York elevated in steps of 5 feet from 10 to 60 feet above the roof.

The results of these tests are shown on Figure 10. Tests B-8 and B-9 show the presence of some minor fluctuations of the received signal as the receiving antenna was elevated beyond about 80 feet, with a marked dip due to reflections at antenna elevations between 150 and 190 feet. The curves *B-8* and *B-9* on Figure 10 cross the line representing free space transmission at receiver elevations of 81 and 91 feet, respectively. Lines representing the center line of the transmission paths at the free space crossover points for Tests B-8 and B-9 are drawn on Figure 9.

Lines *B-8* and *B-9* of Figure 9 cross at about 4.8 miles north of Atlantic, indicating that the controlling obstruction is probably located on hill *D*. Six tenths of a Fresnel Zone for this location is 42 feet, at the test frequency 4,130 megacycles and by plotting this on Figure 9, it is determined that the obstruction extends about 30 feet above the top of hill *D*. Visual inspection indicates that trees located on this hill constituted the controlling obstruction in the path at the time of the tests.

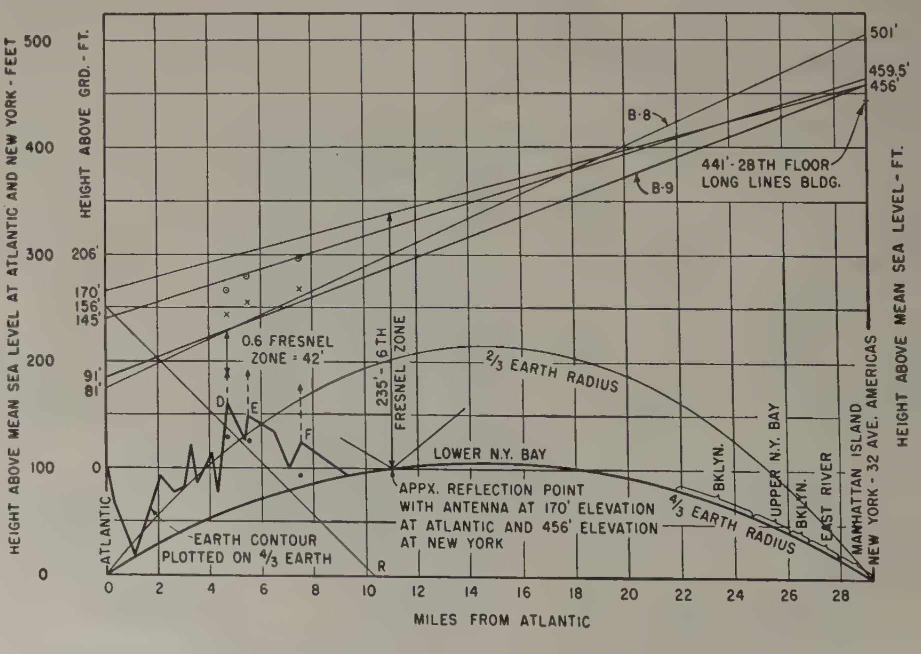


Figure 9 (right). Analysis of tests on Atlantic–New York path, 29.2 miles long

The hills marked *E* and *F* are also of interest and the dotted arrows indicate the approximate height of trees which were found by inspection to be growing on these hills. Under earth bulging conditions corresponding to an effective earth radius of 2/3 the tree tops on hills *D*, *E*, and *F* would reach the points designated *x* with respect to the ends of this path and the circles are plotted to indicate elevations 1/3 Fresnel Zone above the trees under this condition. Likewise the elevation of the top of the trees on these hills under flat earth conditions are shown by the black dots below *D*, *E*, and *F*, respectively.

As it was desired to avoid construction of a tower on the Long Lines Building the elevation of the antenna on this end of this path was fixed at 459.5 feet which is 18.5 feet above the 28th floor roof. Drawing a line from this point just above the circles over hills *D*, *E*, and *F* gives the minimum height required for the antenna at Atlantic as 145 feet above ground.

While the antenna pointing south from Atlantic was to be located 206 feet above ground, this elevation was obviously not suitable for the antenna pointing toward New York because serious reflections from the surface of Lower Bay would be experienced. In fact, reference to Figure 10 indicates the presence of some reflections even at the 170-foot elevation. Hence it was decided to put the antennas pointing toward New York on a platform on the Atlantic tower at the 150-foot level which makes the center line of the antenna 156 feet above ground. An antenna location at a somewhat lower elevation would be preferable, were it not for the obstructions on hills *D*, *E*, and *F* of Figure 9. However, the tests plotted on Figure 10 indicate that the transmission loss over the path will be about equal to free space under normal conditions (4/3 earth radius) using these antenna heights. With greater earth bulging, the water reflection path will be shielded even more due to the trees on hills *D*, *E*, and *F*.

With a flat earth the distance in miles from the Atlantic repeater to the reflection point is given by the formula

$$d=\left(\frac{h_1}{h_1+h_2}\right)D$$

where h_1 = height of Atlantic antenna above sea level
h_2 = height of New York antenna above sea level
D = length of path in miles

From this formula, the reflection point is found to be 10.3 miles from Atlantic. A line from the antenna location to this reflection point (*R* on Figure 9) passes below the black dots indicating the tree tops on hills *E* and *F* under flat earth conditions. Hence it appears that water reflection will be blocked by the trees under this condition also.

Consider again the dip corresponding to a receiver height of 170 feet in the path loss curve *B-9* of Figure 10. The center line of this path has been plotted on Figure 9 between the 170-foot elevation at Atlantic and the 456-foot elevation at New York. Now by inspection it appears that the water reflection for this path under 4/3 earth radius conditions might take place at a point about 11 miles north of Atlantic. At this point the center line of the direct path is measured on Figure 9 as 235 feet above the 4/3 earth surface. The sixth Fresnel Zone radius for a 29.2-mile path is calculated as 230 feet at 11 miles from one end of the path. This is considered to be a fairly good check on the measured clearance of 235 feet at 11 miles and hence it is believed that the 6th Fresnel Zone is responsible for the dip in the path loss curve. This method is also used on overland paths when there are enough dips or "wiggles" in the curves to determine where the reflecting surfaces are located. It will tell the height of the ground and, in many cases, also the tree heights. For example if a nearby hill shields a mid-path bare hill or field when the antennas are lowered preventing a direct determination of the elevation, the discontinuity in the height loss curve caused by reflections from the mid-path location can sometimes be used as indicated to calculate the height of the reflection surface.

LIMITATIONS OF TESTING PROCEDURE

It will be apparent from the foregoing that while microwave testing of proposed transmission paths provides information of great value to the engineer, nevertheless the testing procedure currently in use does have certain limitations. One of these is the fact that testing is normally limited for reasons of economy to relatively short periods of time and hence the results do not show the magnitude or frequency of occurrence of variations in atmospheric conditions which may affect transmission. While the tests are usually made only at times when it is believed that transmission is normal, this is not always possible and the test data must be carefully analyzed in all cases to be sure what conditions are prevailing during the tests. The procedure would be considerably simplified if some simple means of more positive determination of prevailing transmission conditions were available.

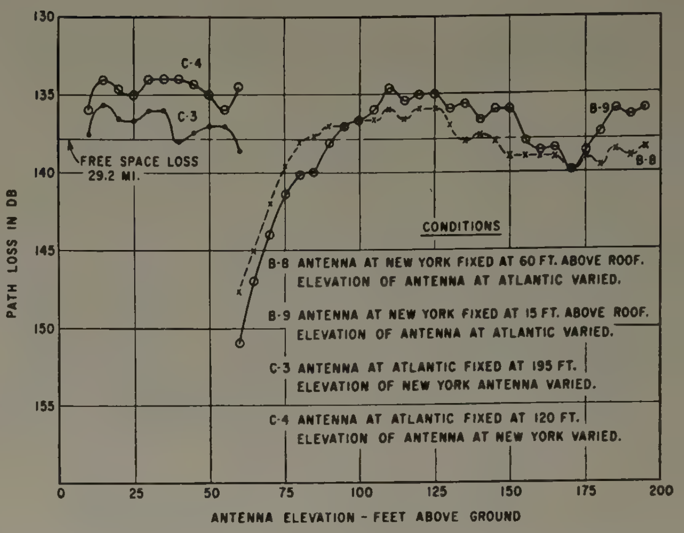


Figure 10. Test results for New York–Atlantic path, 29.2 miles long, with the transmitter at 32 Avenue of the Americas, New York, and the receiver at Atlantic

Another limitation lies in the fact that the tests are made using unmodulated continuous-wave transmissions and it is impossible by this means to distinguish between ground reflections along the desired path and reflections from obstacles which may give rise to transmission over some other path of appreciably greater length. This test limitation was recently brought to light in the establishment of an intercity television circuit into a city of moderate size. Path tests using procedures such as those described in this article indicated that transmission would be satisfactory, although subject to certain reflection effects which were believed to be due to a large body of water in the path. When subsequent tests were made by transmitting a television picture, however, a series of vertical black and white "bars" were observed which were found to be caused by energy overshooting the receiver to strike the face of a large building beyond, from which it was reflected to the face of another large building almost in the transmission path and from there it was reflected directly into the receiving antenna. This double reflection path had a length estimated to be some 12,000 feet greater than the direct path and resulted in a signal delay of approximately 12 microseconds with respect to the main signal. Although the level of this reflected signal was considerably below that of the signal over the direct path, it was nevertheless sufficiently strong to seriously impair transmission, particularly during periods when fading was observed on the direct path. As a result of this experience consideration is being given to the use of modified test equipment which will employ pulse or modulated wave transmissions with receiving equipment capable of measuring the amplitude and time delay of reflected signals.

CONCLUSIONS

As the result of extensive observations and tests it has been concluded that the use of testing techniques similar to those described herein are of great assistance to the engineer in selecting sites and determining optimum tower heights for microwave radio relay stations. Such tests provide information which can not at present be reliably determined by any other means and while the testing work is time consuming and involves some expense, the avoidance of serious problems which otherwise might be encountered after permanent construction is completed is believed to be more than adequate justification for use of this procedure on major radio relay routes.

Isaac Fern Kinnard

Lamme Medalist for 1952

Isaac Fern Kinnard, engineering manager at the General Electric Company, has been awarded the 1952 Lamme Medal "for his outstanding contributions in design and developments in instrumentation and measurements." Mr. Kinnard is the 25th Lamme Medalist

1864 BENJAMIN GARVER LAMME 1924
THE ENGINEER VIEWS HOPEFULLY THE HITHERTO UNATTAINABLE
THE AMERICAN

The Establishment of the Medal

L. L. BOSCH
FELLOW AIEE

NATHANIEL HAWTHORNE'S literary classic "The Great Stone Face" teaches us to look close about for strength of character, for steadfastness, for inspiration, and the many other manifestations of simple greatness that cannot help but leave a lasting impression on the sands of time. It is a beautifully simple lesson by a great American novelist and through the years has provided many with stimulus and inspiration to character development and melioration.

Also through the years, Benjamin G. Lamme has been a "Great Stone Face" for the professional inspiration and guidance of many electrical engineers. The Lamme Gold Medal was estalished in 1924 by the AIEE in accordance with a bequest of Mr. Lamme which provided for an annual award by the Institute to a member who had shown meritorious achievement in the development of electric apparatus or machinery.

Mr. Lamme, a mechanical engineering graduate of Ohio State University in 1888, had a lifetime association with the Westinghouse Electric Corporation, where he served as chief engineer from 1903 until his death in 1924. Those who had the privilege of knowing and working with Mr. Lamme point to three traits that seem especially characteristic of this great engineer.

First, they relate, his work was his life. Undoubtedly because of this singleness of purpose throughout his life, he made the greatest possible use of his keenly analytical mind and exceptional engineering foresight. He had a great capacity for intensive continuous work, to which he coupled the philosophy that when one works to accomplish something of benefit to the world just reward will come with its accomplishment.

Second, his associates point out that Mr. Lamme was one of those who pioneered truly scientific design methods. His technique was first to visualize his problem, analyze the conditions, and proceed with fundamental principles to obtain the desired result. Calculation was substituted for cut and try methods and abstract formulas. This approach resulted in the creation of new species, not simply improvements in design.

Third, it is well known that Mr. Lamme's engineering genius was contagious. One of his keenest personal interests and contributions to engineering was that of guiding and developing young engineers in design, and his ability as a teacher was remarkable. He organized and personally instructed picked groups of engineers in an intensive study program on the fundamentals of design of electric machinery.

Each year in accordance with Mr. Lamme's bequest, the AIEE, somewhat in keeping with the spirit of the legend of the "Old Man of the Mountains," looks close about and selects one of its members who has raised the art of the development of electric apparatus and machinery to a higher tone—looks to another "Great Stone Face."

Career of the Medalist

EVERETT S. LEE
FELLOW AIEE

ONE OF THE pleasures of life is to tell of outstanding engineering accomplishments; and as I describe the engineering achievements of Isaac Fern Kinnard, I will be talking about a friend whom I have known and have lived with in engineering association for 30 years.

Prominent among Mr. Kinnard's contributions has been the advance in the development and design of the watt-hour meter, the little device mounted usually in the basement or on the outside of the house or factory where it measures the amount of electricity used in order that you may be billed for it correctly. Obviously it must be accurate; accuracy is its prime requirement.

I remember a dinner meeting in Swampscott, Mass., in 1939, to celebrate the golden jubilee of General Electric watt-hour meter manufacture at West Lynn. Leverett Saltonstall, then governor of Massachusetts and now

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Essentially full texts of the presentation and acceptance addresses given at the Lamme Medal ceremony held during the AIEE Summer General Meeting, Atlantic City, N. J., June 15–19, 1953.

L. L. Bosch, Chairman of the Lamme Medal Committee, is a partner, Bosch and LaTour, Cincinnati, Ohio.

Everett S. Lee, past president of the AIEE, is manager of Technical Public Relations Services, General Electric Company, Schenectady, N. Y.

United States Senator, was the speaker. I remember him telling a story in which he said:

> I go into my basement and there is the water meter. I listen and I hear it go click, click, click. Then there is the gas meter, much larger, and I listen and I hear it go click, click. And then there is the electricity meter. It is much smaller. I listen and there is no sound. But the bill comes around at the end of the month just the same.

That electricity meter is the watt-hour meter which involves Mr. Kinnard's contributions.

Isaac Fern Kinnard was born in Ontario, Canada, September 29, 1891. Watt-hour meters were surely in the stars that year, for earlier George W. Walker had presented, at a meeting of the Institute in New York, N. Y., a paper containing an analytical discussion of the relative merits of the meters for power measurement in those early days of the electrical industry.

Twenty-seven years later, in 1918, Kinnard was graduated from Queens University, Kingston, Ontario, with a bachelor of science degree, having majored in electrical engineering and physics. After service in the Engineers Corps, Canadian Army, during World War I, he attended the University of Glasgow as a graduate student in mathematics and physics. From 1919 to 1922 he was a research engineer with the Westinghouse Electric Corporation, where he contributed to the magnetic analysis of materials and to the development of magnetic materials as applied to transformers and machines.

In 1922 Kinnard joined the Meter and Instrument Department of the General Electric Company at West Lynn, Mass., as a research engineer. There he was associated with those pioneer engineers and leaders, Elihu Thomson, Frank P. Cox, and William H. Pratt. Like the young engineer coming into industry today with a rich heritage from the engineers who have preceded him, Kinnard found there was still an abundance of problems ahead for the application of his abilities.

The watt-hour meters of that day were of substantial design, but their accuracy was limited in temperature range. Their overload capacity was 150 per cent. Kinnard saw the value of extending this temperature range even though these errors were at most only 0.07 per cent per degree centigrade. But here was a challenge to provide a better meter, and Kinnard applied himself to it. He enlisted the abilities of H. T. Faus, who was a magnetic materials metallurgist, physicist, and engineer; for Kinnard always recognized the value of teamwork in engineering accomplishment.

The sources of the errors they were studying were complicated. To analyze them they adopted the experimental procedure of selecting one possible variable and holding it constant while the temperature was changed, noting the result on the meter's performance. This is a fundamental procedure, but one which only too often is not systematically used.

From this procedure, followed by an analysis of the results, came the revelation of the effect of the errors. These Kinnard separated into two categories bearing the following designations: *Class I*—those primarily in the retarding magnets, affecting the magnitude of the useful fluxes. *Class II*—those primarily in the potential element, affecting the phase relation of the useful fluxes.

Then followed the development and design of a means for neutralizing the retarding errors for which Kinnard was granted his first patent on March 19, 1929: Number *1,706,171*, "Temperature Compensation for Magnets, Class *I*." (Seventeen other patents have been awarded Kinnard since, four of them jointly with engineers associated with him.)

This accomplishment by Kinnard was of great significance. Dr. H. B. Brooks of the United States National Bureau of Standards in discussing it said:

> The paper by Kinnard and Faus is important and valuable, not only for its definite data and clear reasoning, but also because it is a tangible indication of the interest which is being taken in the question of the accuracy of metering. I think the authors are to be congratulated on their neat and simple solution of the matter of Class *I* errors.

The immediate effect of his accomplishment in meter performance was to decrease temperature errors by 85 per cent. In addition, the overload capacity was increased from 150 to 250 per cent. It was also possible to operate the improved meter over an ambient-temperature range of from −40 to +50 degrees centigrade, or an increase of six times the previous range. The meter having these improved characteristics was announced by General Electric in 1926.

Further in the discussion of this accomplishment can be found another most significant statement, made by Frank B. Magalhaes of the New York Edison Company:

> Progress can be considered as going forward by slow steps, and after a step forward has been taken there is a search or analysis made on that step to develop all the possibilities that may be obtained. Without any doubt, this step forward will be followed by a considerable amount of research to develop all the possibilities that the step may offer....

This surely was prophetic of Kinnard, for he continued his development activities on the watt-hour meter to make it even better. Thus it was that he announced in 1937, with H. E. Trekell, a new watt-hour meter with overload capacity of 400 per cent, with temperature compensation at all power factors, and, approximately 2 years later, with a completely new design of retarding magnets of the new material Alnico II to give performance against the demagnetizing effects of surges caused by lightning voltages on the power distribution lines.

One would think that this was surely the end—but Kinnard had been devoting his attention to the meter bearings because they limited the length of operation in service. These are the bearings which support the very light rotating disk and shaft, the mechanism which Governor Saltonstall could not hear as it rotated and moved the counting mechanism. With J. H. Goss, Kinnard had studied the bearing behavior and had reported upon it to the Institute. However, still not satisfied with the limitations of the bearing performance, he said: "Let us get rid of the bearings altogether." He envisioned the moving element suspended in a magnetic field, thus eliminating the conventional bearings and providing unlimited service life with sustained high accuracy and no required maintenance. Here surely was boldness of concept.

The magnetic suspension of a watt-hour-meter rotating element had been tried many years before, but the early designs had been limited by the lack of suitable permanent magnet materials. Through magnetic material research, inspired and directed by Kinnard, these had now become available. Thus, by diligent application of the new materials and by solving the new force system fundamental in a magnetic suspension, Kinnard, with Sturtevant, Trekell, Mendelsohn, and Wright, announced a totally new watt-hour meter in 1948, with up to 400 per cent overload capacity, with magnetic suspension of the rotating element, with Alnico V magnets for improved surge resistance, with co-ordinated insulation system, and with improved calibration stability to allow certification of accuracy and to provide unlimited service life without maintenance.

That such continuous advances in performance could be designed into such a small and relatively simple mechanism as the watt-hour meter of 1926, with temperature compensation, proves again that there is always a better way. It is to the glory of the engineer that he always searches it out.

While all of this accomplishment in watt-hour meter development and design was in progress, Kinnard's advancement in engineering and management responsibility was continuous. When he became manager of engineering for the Meter and Instrument Department in 1930, he applied himself to new and expanding fields of instrumentation and measurements. To each of these he brought his ability to look ahead and see the opportunities for accomplishment, to inspire his associates to analyze each situation and break it down into its significant factors, to deputize the problems to scientists and engineers possessing the abilities necessary to arrive at a solution, to assess the performance of the solution, and to proceed to carry it out.

As a guide in engineering achievement, Kinnard evolved for himself and his engineers the standard of the Meter and Instrument Department symbolized by the code word TAMSA. The letters of this word form the initials of the following:

1. Technical excellence.
2. Attractive appearance.
3. Mechanical nicety.
4. Suitable manufacturing cost.
5. Availability at the proper time.

These are five qualities that every design should have. They are fundamentals for the design of any product.

Fabian Bachrach

I. F. Kinnard

In the field of switchboard instruments, I well remember Kinnard telling us, in the early 1930's, that the scales of switchboard instruments should be longer—300 degrees rather than the 90 degrees which was conventional at that time. Applying his usual principles to the idea of team development, the 240-degree long-scale concentric instrument was brought into successful accomplishment in the late 1930's. This provided an instrument more easily read and yet requiring much less panel space than previously. This new instrument became available at just the right time, for, with high shock mounting characteristics, it was adopted by the Navy as an immediate requirement for all submarines and ships of war. Kinnard's vision was our nation's gain.

Kinnard's personal interest in photography brought his talents into this field to advance that science through measurements. With a team headed by Allen Stimson, this work resulted in the development of a universal exposure meter of high sensitivity for all normal photographic purposes. This was followed by an improved meter of the very smallest size and lightest weight, once more marking an advance in instrumentation. Later this work produced a special-purpose exposure meter to be mounted directly on a camera for immediate picture development.

In the field of measurement of nonelectrical quantities, Kinnard had advanced the application of electrical measurement and made it widespread. Here there are being produced under his direction a great variety of instruments for the measurement of thickness, mass, time, volume, rate of flow, temperature, pressure, strain, surface roughness, vibration, speed, light, brightness, sound; virtually any quantity where the advantages of electrical measurement are useful.

In the field of aircraft instruments for automatic flight control, Kinnard has advanced electrical developments and designs to outstanding usefulness and application. He conceived the electrically driven gyro to replace the air-driven type, and this design has become the design of the field. In addition there is a host of other aircraft instruments for advanced aircraft performance and for jet-engine control. The latest of these, the mass flowmeter, which applies a new principle to the measurement of fuel flow in aircraft, has extremely low pressure drop and functions independently of the specific gravity of the fuel. This outstanding development is typical of Kinnard's achievements through engineering teamwork of able scientists and engineers.

In the field of instrument transformers, Kinnard has pressed forward constantly with advances in design. Techniques for molding instrument transformers in butyl rubber, developed in 1949, marked the first application of this modern material to the complete insulation of an electric device.

The monument to the engineer is the products he designs; but the relations of the engineer with his fellow engineers, although not so tangible, live on in the hearts of men. This relationship is typified in the beautiful Measurements Laboratory at West Lynn, which is a symbol of an outstanding measurements engineering organization. In creating this organization, Kinnard has advanced the professional development of many capable engineers. He has taken a direct personal interest in their individual progress, their educational activities, and their recreational facilities. From his Measurement Laboratory and Engineering Department many outstanding engineers have gone into other departments of the General Electric Company, there to become leaders and to augment in their respective ways the principles of engineering accomplishment so typical of Kinnard's life.

Foremost among these principles, and always present in Kinnard's engineering life, I put the constant urge to look forward. His energies are directed always to the new, always toward improvement, always to a better way.

On the wall above Kinnard's desk hangs the slogan: "The Price of Progress Is Trouble." So it is, but with "Doc" Kinnard, as we all like to call him, the troubles are dissolved in the satisfactions of achievement.

As a young engineer I was privileged to hear and meet the late, great, Benjamin G. Lamme. To Kinnard I am sure he would say:

> Well done—for outstanding contributions in design and developments in instrumentation and measurements.

Truth and Measurement

I. F. KINNARD
FELLOW AIEE

WHEN I READ Mr. Lee's glowing tribute, I cannot help wondering whether I really deserve the very complimentary statements he makes. It is with a great deal of pride and appreciation, however, that I accept this award. When I consider the achievements of those who have received the Lamme Medal in the past, I feel especially privileged to be included in that group so highly honored by the AIEE.

I am also mindful of the fact that the bestowing of this award is a great tribute to my many associates. Their loyalty, creative ability, and hard work have made possible many of the accomplishments that Mr. Lee has mentioned here.

I never had the privilege of knowing Mr. Lamme personally. This I deeply regret because I am aware that his ability and leadership have been a source of great inspiration to all those who did know him. However, I could not help being conscious of his great engineering leadership. This was particularly evident to me during my brief association with the Westinghouse Research Laboratory many years ago.

My interest in the electrical industry has been mainly in the field of measurements. I believe that reliable measurements are most valuable, and actually indispensable, in determining the truth regarding most matters, particularly any scientific undertaking. Therefore, I should like to express briefly some of my thoughts on the subject of truth and measurement.

Engineering is a profession of which we can be justly proud. Over the years no group has contributed more to the cause of humanity, at least in a material way, than those we now call members of the applied science or engineering profession. The reason for this success is that the engineer's work, by its very nature, must be based on sound principles. The engineer is constantly in search of the truth of the matter and the means of applying known facts of physics and of materials to his activities. This is a heritage and an obligation which reaches way back into history.

SUCCESSFUL ENGINEERING BASED ON TRUTH

AS A YOUNG man, I chanced to walk by the New York Public Library. There, engraved near the entrance, is this inscription: "But above all things, Truth beareth away the Victory." This appears to state the real essence of engineering and it made a profound and lasting impression on me. At that time, and many times since, these words have given me new courage to go on to a successful solution of seemingly impossible technical problems. It was some years later when I found that the quotation is from the first book of Esdras, one of the apocryphal writings found among the ancient Hebrew scriptures.

"But above all things, Truth beareth away the Victory"—how appropriately this statement, now over 2,000 years old, applies to the present creed of engineering and how aptly it expresses the entire history of the profession. It is perhaps possible, through ignorance or intent, to ignore the truth for a time, but engineering work based on anything less than the truth is doomed to eventual failure—and experience has shown there can be no compromise with this principle.

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In much of our work, of course, we apply known technical information, but real progress usually comes from the discovery by physicists and other scientists of new scientific facts. These are the truths that "open the door" for the creative engineer, allowing him to make further practical advances for the benefit of mankind.

MEASUREMENT DETERMINES THE TRUTH

Man's increasing ability to understand nature's secrets and to discover new scientific truths comes largely from his success in making accurate measurements. Likewise, the engineer finds that his problems become easier, and often quite simple, when he can measure and evaluate the facts of any given situation.

In 1883, Lord Kelvin made the famous statement that I quote in part:[1]

> When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind...whatever the matter may be.

If this is not the first authoritative statement to establish the status or importance of measurements, it is at least one of the best known. Lord Kelvin's observation concerning measurements is even more pertinent now than it was in his day.

MEASUREMENTS IN BASIC SCIENCE

In all things the truth exists, but it is sometimes well hidden from those who seek it. In the study of physical phenomena, measurements and theory must go hand in hand. A useful theory explains and predicts; then measurements become the final test of the truth of the theory. If measurements do not confirm the theory, an analysis of the measurements frequently indicates the new direction the theory must take. One example will illustrate this point.

Twenty years ago, a young Italian physicist named Enrico Fermi bombarded various elements with neutrons. He found that the usual result was to convert the bombarded element into the next higher in the periodic table. This raised a challenging question: What happens when the highest known element in the table is bombarded? Will uranium be converted into a new and heavier element?

This exciting experiment was soon performed, but the results were inconclusive. They indicated that uranium had been transmuted to not one, but to a number of different elements, and no systematic explanation of the observation could be given.

Five years later, in 1939, Hahn and Strassman in Germany announced that their more accurate measurements of radioactivity half-life and precise chemical analyses had solved the mystery. It was shown that uranium undergoes nuclear fission breaking up into barium and other lighter elements and releasing tremendous amounts of energy. Precision measurements thus led to a revision in theory and ushered in the "Atomic Era."

This awesome new power source, atomic energy, now at man's disposal, presents many new technical problems. Science currently is making available important new measurement techniques to assist in its utilization and in health protection.

MEASUREMENTS IN APPLIED SCIENCE

Many examples of well-known engineering developments in which measurements played an important part could be enumerated. Some of these involve a large number and wide variety of measurements to obtain the necessary data. Others may be of such a nature as to require an especially difficult or significant measurement which is indispensable to the solution of the problem.

The development of a modern watt-hour meter requires a careful investigation of many new materials and design advances. It is somewhat startling to discover that in order to conclude successfully such an important development, more than 150 separate quantities or conditions must be accurately measured. These include electricity, sound, heat, time, mass, mechanical power, magnetism, the usual lineal measurements, together with many chemical and metallurgical phenomena. The total number of individual measurements involved reaches hundreds of thousands, and may require years to complete.

Equally impressive are the routine quality-control measurements required in the manufacture of many products. Take, for example, the operation of balancing a gyroscope used as a flight-control instrument in aircraft. Here, high-precision electronic measurements are made to align the center of gravity of the spinning mass with the gimbal bearings. This adjustment must be made within ten millionths of an inch. Measurements of this order are becoming commonplace in modern factory operations.

These are but two of the countless examples, which could be cited, of the part measurement plays in the application of science to modern industry.

MEASUREMENTS AND CYBERNETICS

Measurement determines the values of the constants or variables with which we are concerned. The modern trend, however, is to provide electromechanical means for taking any necessary action as the result of such measurement. In so doing, mechanisms are actually performing to some degree the work that man's brain and nervous system previously had to do. This analogy and the actual studies and applications of automaticity recently have been termed "Cybernetics,"[2] and this word now has found its way into the dictionary.

For example, great progress has been made through the years in the development of automatic business machines and computers that perform complex mathematical calculations. Such machines will solve problems faster and more accurately than man previously did by hours of mental drudgery. To do this, however, they must be supplied first with the basic measured data.

Another important companion function to measurement is that of control. In factories where products are manufactured in a continuous or batch process, such variables as temperature, pressure, flow, liquid level, color, and so forth, are held at proper values by automatic control equipment. Before the variable can be held at a desired value, it is first necessary to determine when that value has been reached, and when, and by how much, and how fast it deviates from the desired value. This is the function of measurement. Important new developments are aiming toward the production of measurement systems to detect, measure, and initiate control of such variables with greater reliability and automaticity. Thus, accurate, dependable measurements present the facts; control equipment acts upon them. This is a part of the trend which involves the gradual change from the use of man's efforts to those of machines.

SUMMARY

In summary, I am sure that you, as scientists and engineers, will accept the precept that truth must be determined and that all the factors involved must be properly measured to insure that action be based upon facts. Particularly in the material things of life there is no reason to doubt that "truth beareth away the victory."

Unfortunately, the basic concept that the facts must be obtained before ultimate success can be achieved is as yet little understood or practiced in many spheres of human activities. It was the late Professor Elihu Thomson who made the following significant comment in a talk before the Franklin Institute in Philadelphia shortly before World War I:

> We will eliminate war, that horrible spectre which menaces civilization...when we obliterate greed, dishonor, and bitterness from men's minds and...substitute, for these evils, candor, and generous regard, with a passion for the real truth of things in our relations in life.

Let us hope that the same searchlight of truth, so indispensable to scientific progress, finally will penetrate the policies and actions of those responsible for just and peaceful relationships among the peoples of our nation and of the world.

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The Magnetic Amplifier

W. C. JOHNSON
MEMBER AIEE

An elementary magnetic amplifier is considered with and without control current flowing and its limitations are discussed; then a magnetic amplifier with external feedback is examined and the advantages pointed out; finally self-saturating circuits are evaluated.

IT IS WELL KNOWN that the impedance of an iron-cored coil can be varied by changing the degree of saturation of the core, and this principle has been used for many years in a few simple control circuits. A typical circuit is shown schematically in Figure 1, where the impedance of the two iron-cored inductors is used to control the current in the load. The direct current in the control winding determines the saturation of the cores and hence the impedance of the series windings. The traditional name for the control inductor was *saturable reactor*, and the entire circuit now is called a *magnetic amplifier*, since only a small amount of control power is normally needed to control a considerably larger amount of power in the load. The original saturable-reactor circuits received comparatively little use because of inherent limitations in power amplification and response time. Although the basic idea behind the device seemed quite simple, the actual principles of operation were more complex than was generally realized. This was one of the major reasons for the delay in the development of the device.

In a first analysis of the magnetic amplifier, it is helpful to make certain simplifying assumptions which, while they make the analysis easier to follow, do not greatly

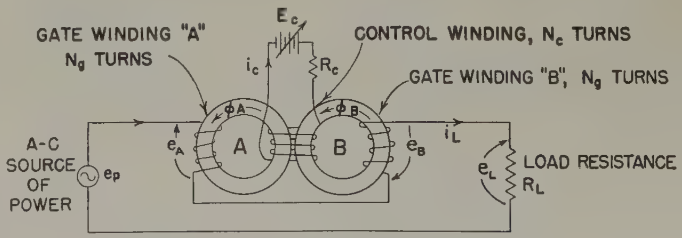

Figure 1. Elementary magnetic amplifier

Revised text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953, and recommended for publication by the AIEE Committee on Magnetic Amplifiers. This is the first of a series of articles on the magnetic amplifier scheduled for publication in subsequent issues.

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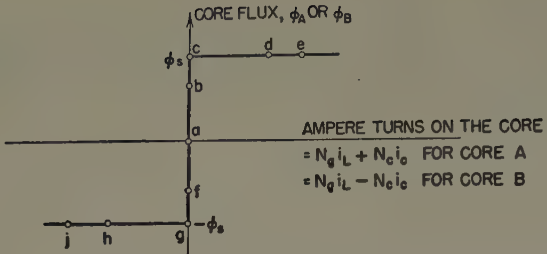

CORE FLUX, ϕ_A OR ϕ_B
ϕ_s
c
d
e
b
a
AMPERE TURNS ON THE CORE
$= N_g i_L + N_c i_c$ FOR CORE A
$= N_g i_L - N_c i_c$ FOR CORE B
f
$-\phi_s$
j
h
g

Figure 2. Idealized magnetization curve

alter the basic features of operation. The assumptions made here to start with are: (1) that the load is a resistance; (2) that the control circuit offers a reasonably low impedance to alternating currents; (3) that, instead of a hysteresis loop, the magnetization characteristics of the core material have the idealized form shown in Figure 2. A large control-circuit resistance will alter the waveforms somewhat from those shown here, but the effect on the control characteristics is not a major one.

THE ELEMENTARY MAGNETIC AMPLIFIER

THE SATURABLE REACTOR of Figure 1 consists of two identical ferromagnetic cores wound with identical "gate" windings and a common control winding. The gate windings are connected so that the load current will tend to produce fluxes in opposite directions through the control winding, as otherwise this winding would act like the secondary of a transformer.

When the control current is zero, the saturable reactor offers a high impedance and the load current is small. When a control current is applied, the cores saturate and permit load current to flow. However, the two cores saturate and unsaturate at different points in the cycle and, to understand the operation of the device, it is necessary to follow the instantaneous operation in detail through one steady-state cycle. The procedure will be to assume instantaneous starting points for all quantities at the beginning of the cycle and then follow the operation graphically through the cycle. If the starting points are chosen correctly for the steady-state condition, all quantities will return to their original values at the end of the cycle.

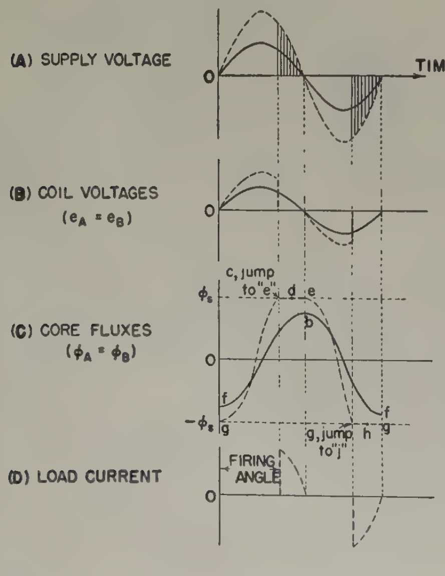


Figure 3. One cycle of operation with zero control current, shown for two different amplitudes of supply voltage

The Elementary Magnetic Amplifier With Zero Control Current: First, consider the operation of the magnetic amplifier of Figure 1 when the control circuit is open. Neglecting coil resistance, the two coil voltages are related to the core fluxes by the equations

$$e_A = N_g \frac{d\phi_A}{dt} \times 10^{-8} \quad \text{and} \quad e_B = N_g \frac{d\phi_B}{dt} \times 10^{-8} \tag{1}$$

or, conversely, the change in core flux is given by

$$\Delta\phi_A = \frac{10^8}{N_g} \int e_A dt \quad \text{and} \quad \Delta\phi_B = \frac{10^8}{N_g} \int e_B dt \tag{2}$$

where N_g is the number of turns on each gate winding, e_A and e_B are the two instantaneous gate-winding voltages, and ϕ_A and ϕ_B are the two instantaneous core fluxes in maxwells. Note that the change in core flux is proportional to the "volt-second area" applied to the core winding.

The steady-state waveforms of voltage, flux, and current are shown in Figure 3 for two different values of supply voltage. First examine the solid curves, which are drawn for a moderate value of supply voltage. The two coils, being identical, will divide the supply voltage equally between them. Since the coil voltages are sine functions, the core fluxes will be negative cosine functions, as shown. Comparing Figure 3*C* with Figure 2, each core flux will take the path *fabaf*, and the current in the circuit (neglecting hysteresis) will be zero through the whole cycle.

Now examine the dashed curves of Figure 3, which are drawn for a larger supply voltage. Tentatively choosing a starting point for core fluxes at negative saturation, the fluxes build up according to equation 2 as a negative cosine function but reach positive saturation before the end of the half-cycle (path *gac* in Figure 2). At this point the core fluxes cannot increase further, but can only remain constant at the saturation value. With zero rate of change of flux, equation 1 shows that the coil voltages become zero. In other words, because of the saturation of the cores, the coils offer zero impedance and are the equivalent of short circuits. The supply voltage is now impressed entirely across the resistive load, as shown by the shaded portion of Figure 3*A*, and load current flows as shown in Figure 3*D*. The electrical angle at which conduction starts is often called the "firing angle." Referring to Figure 2, the sudden flow of current causes a jump out along the current axis to point *e*, after which the operating point moves gradually back and reaches point *c* when the current is zero at the end of the half-cycle. In the next half-cycle, the supply voltage reverses and brings the core fluxes down in cosine fashion according to equation 2. Negative saturation is finally reached, and a negative pulse of current flows through the load. The end of the cycle finds the core fluxes back at the starting point. The unusual features of the circuit are: (1) No load current flows until the amplitude of the supply voltage is above a certain critical value. (2) Beyond this critical value of supply voltage, the current has the waveform shown in Figure 3*D*. The firing angle is reduced as the supply voltage is increased further.

The supply voltage is generally selected so that, in the absence of control current, the core fluxes almost, but not quite, reach the saturation point. Except for a small magnetizing current, similar to that of a transformer, the load current is zero when the control current is zero.

The Elementary Magnetic Amplifier With Control Current Flowing. Reference to Figure 1 shows that a control current will apply magnetomotive forces in opposite directions in the two cores. As a result, the two core fluxes no longer will be equal as in Figure 3*C*, but one flux will be displaced upward and the other downward. To analyze the effect of a control current, again assume instantaneous starting points for all quantities and then follow through one cycle of operation graphically. The d-c value of control current then can be found as the average value of i_c. By trial and error, the starting points that produce steady-state operation are those shown in Figure 4, with i_c and i_L both instantaneously zero, ϕ_B starting at $-\phi_s$ but immediately rising out of saturation, and ϕ_A starting at some intermediate value. It is at first surprising that the control current should be zero in the prefiring interval although there is a direct voltage source in the control circuit. The control current turns out to be a pulsating current because of the coupling with the gate coils, and the d-c component of this pulsating current is equal to the control-battery voltage divided by the control-circuit resistance. With both control and load currents instantaneously zero throughout the prefiring interval, both cores are unsaturated during this period (see Figure 2). The actual starting point of ϕ_A in Figure 4 depends on the value of d-c control current; however, the problem will be worked backwards by assuming a starting point for ϕ_A and then determining the corresponding d-c value of control current.

It is found that the cycle can be divided into four distinct parts, similar to those of Figure 3, and these parts are shown in Figure 4. In addition to the waveforms, Figure 4 shows an equivalent circuit in which the one common control coil is replaced by its equivalent of two separate control coils of N_c turns each, connected in series opposition.

In the first part of the cycle, the two gate windings are coupled together through the low-impedance control circuit and, through the resulting transformer action, are forced to divide the supply voltage almost equally. Both fluxes rise according to equation 2.

When core *A* saturates at $\phi_A = \phi_s$, the first mode terminates and the second mode begins. The flux ϕ_A holds constant, collapsing e_A to zero, and e_B is very small because it is now short-circuited by the low-impedance control circuit. Since e_B is very small, ϕ_B remains nearly constant. With both gate-winding voltages nearly zero, the supply voltage is impressed across the load, and load current flows. The control circuit, through its close coupling with load coil *B*, carries the current $i_c = i_L N_g / N_c$, where N_g is the number of turns on one gate winding and N_c is the number of turns on the control winding. Thus, in the second part of the cycle, inductor "*B*" acts like a current transformer between the load and control circuits.

At the beginning of the next half-cycle the supply voltage reverses, bringing core *A* out of saturation. Now both cores are again unsaturated and the circuit is back to the conditions of the first mode except that all polarities are reversed.

When core *B* saturates, the last mode begins. This is like the second mode except that the control circuit is now coupled to coil *A* instead of coil *B*, and so the reversed i_L produces an i_c in the same direction as before. The result is a unidirectional pulsating current in the control circuit, the d-c component of which must be supplied from the control source (Average $I_c = E_c/R_c$) in order to maintain the assumed operating conditions.

Two points now should be noted:

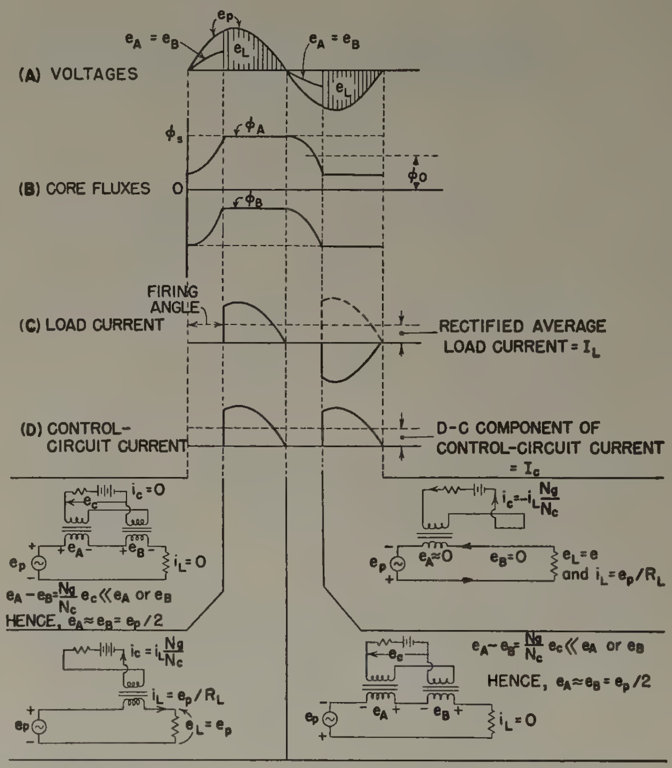

(A) VOLTAGES
e_p
$e_A = e_B$
e_L
$e_A = e_B$
e_L
ϕ_s
ϕ_A
(B) CORE FLUXES
0
ϕ_0
ϕ_B
FIRING ANGLE
(C) LOAD CURRENT
RECTIFIED AVERAGE LOAD CURRENT = I_L
(D) CONTROL-CIRCUIT CURRENT
D-C COMPONENT OF CONTROL-CIRCUIT CURRENT = I_c
$i_c = 0$
e_c
e_A
e_B
e_p
$i_L = 0$
$e_A - e_B = \frac{N_g}{N_c} e_c \ll e_A$ or e_B
HENCE, $e_A \approx e_B = e_p/2$
$i_c = i_L \frac{N_g}{N_c}$
$i_L = e_p/R_L$
e_p
$e_L = e_p$
$i_c = -i_L \frac{N_g}{N_c}$
e_p
$e_A \approx 0$
$e_B = 0$
$e_L = e$
and $i_L = e_p/R_L$
$e_A - e_B = \frac{N_g}{N_c} e_c \ll e_A$ or e_B
HENCE, $e_A \approx e_B = e_p/2$
e_c
e_p
e_A
e_B
$i_L = 0$

Figure 4. One cycle of operation of the elementary magnetic amplifier

1. On a one-to-one turns basis, the d-c component of the control current is equal to the rectified average value of the load current. Using average values,

$$N_c I_c = N_g I_L \tag{3}$$

where I_c is the direct current in the control circuit, I_L is the rectified average value of the load current, and N_c and N_g are the turns on the control and gate windings respectively. When the d-c control current is zero, the firing angle is 180 degrees (no firing at all), and the load current is zero. As the control current is increased, the cores "fire" earlier (firing angle reduced) so as to maintain equality between the d-c control ampere turns and the rectified-average ampere turns of each gate winding. When the firing angle has been reduced to zero, the supply voltage is impressed across the load throughout the whole cycle. The load current cannot increase beyond this point, and remains constant if the control

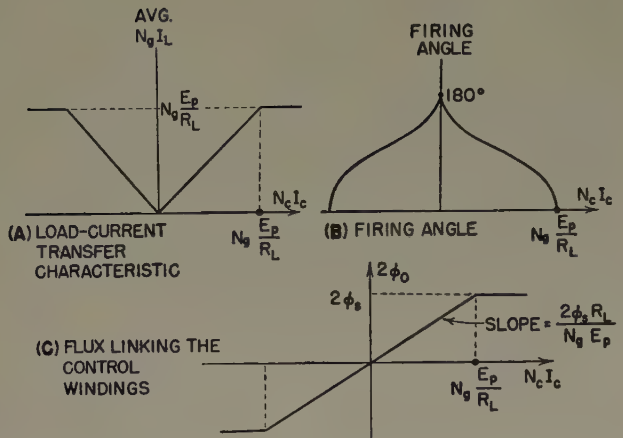


Figure 5. Control characteristics of elementary magnetic amplifier. The quantities I_L, I_c, and E_p are average values

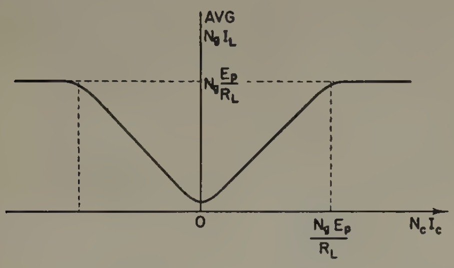


Figure 6. The effect of a nonideal core on the transfer characteristic

current is increased still further. These relations are shown in Figures 5*A* and 5*B*. Negative control current produces the same saturating effect as positive control current.

If the load current is rectified, its d-c component will be in direct proportion to the d-c value of the control current, as shown by equation 3. This relationship is sometimes called the "d-c transformer law" of the saturable reactor.

2. The average flux linking the windings of the control circuit is the average value of $\phi_A-\phi_B=2\phi_o$ (see Figure 4*B*). This flux increases uniformly with control current until the firing angle is zero, at which point $\phi_o=\phi_s$. Further increase in control current produces no additional increase in control-winding flux. This relationship is important in calculating the time constant of the control circuit, and is plotted in Figure 5*C*.

The foregoing relations, it will be recalled, are based on the idealized magnetization curve of Figure 2. Figure 6 illustrates the effect on the transfer characteristic of a nonideal core as compared with Figure 5*A* for the ideal core. The load current is not quite zero at $I_c=0$ because of the finite permeability of the core and the hysteresis and eddy-current losses. The curve has a round knee at the top because the magnetization characteristics of the iron have a similar knee. With the best magnetic materials, these imperfections are not very noticeable.

Limitations of the Elementary Magnetic Amplifier—Gain and Time Constant. Assume that the output current of the magnetic amplifier is rectified and that the useful output is the d-c component of this current. Assume also that zero control current corresponds to zero load current, as shown by the idealized transfer characteristic of Figure 5*A*. The power gain of the magnetic amplifier can be written as

$$G=\frac{\text{Useful Load Power}}{\text{Power From Control Source}}=\frac{I_L^2R_L}{I_c^2R_c} \qquad (4)$$

where I_L is the average value of the load current and I_c is the d-c component of the control current.

Since, from equation 3, $I_L/I_c=N_c/N_g$ over the working range of the amplifier, equation 4 reduces to

$$G=R_L/R_c' \qquad (5)$$

where R_c' is the control-circuit resistance referred to the load-winding turns:

$$R_c'=R_c(N_g/N_c)^2 \qquad (6)$$

Since inductance is the flux linkage per unit current, and the flux linking the control winding is $2\phi_o$, the time constant of the control circuit can be written as

$$t_c=L_c/R_c=(1/R_c)\{N_c(2\phi_o)/I_c\}\times10^{-8}\text{ seconds} \qquad (7)$$

According to Figure 5*C*, $2\phi_o=(2\phi_sR_L/N_gE_p)N_cI_c$. Hence, equation 7 can be written as

$$t_c=(2\phi_sR_LN_c^2/E_pN_gR_c)\times10^{-8}\text{ seconds} \qquad (8)$$

For a given amplifier, this is smallest when the supply voltage (E_p) has the largest permissible value, that is, when the volt-second area of one voltage loop is just sufficient to drive the flux from $-\phi_s$ to $+\phi_s$. The voltage across one gate winding is half the supply voltage, and the time of one loop is $1/2f$ seconds; hence, using equation 2:

$$2\phi_s=(10^8/N_g)\times(\text{Avg. }E_p/2)\times(1/2f)$$

or,

$$\text{Largest Permissible }E_p=8N_g\phi_sf\times10^{-8}\text{ average volts} \qquad (9)$$

where f is the frequency of the driving source.

Substituting this value of E_p into equation 8, the time constant becomes

$$t_c=R_L/4fR_c'\text{ seconds,}\quad\text{or}\quad \tau_c=R_L/4R_c'\text{ cycles.} \qquad (10)$$

The ratio of gain to time constant is, from equations 5 and 10,

$$G/t_c=4f\quad\text{or}\quad G/\tau_c=4. \qquad (11)$$

Equation 11 indicates the basic limitation of the elementary magnetic amplifier: A reasonable gain is accompanied by a sluggish response, and a fast response can be obtained only by making the gain quite low. Another way of saying this is that the gain-bandwidth product of

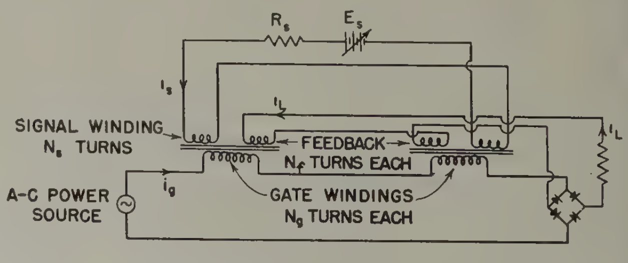


Figure 7. Magnetic amplifier with external feedback

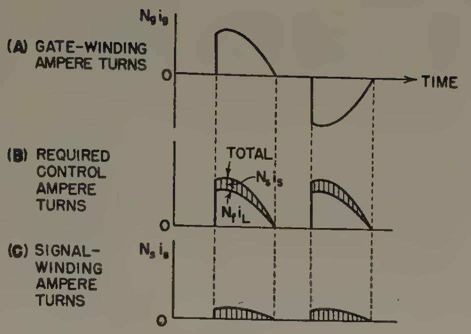


Figure 8. Waveshapes in circuit with external feedback

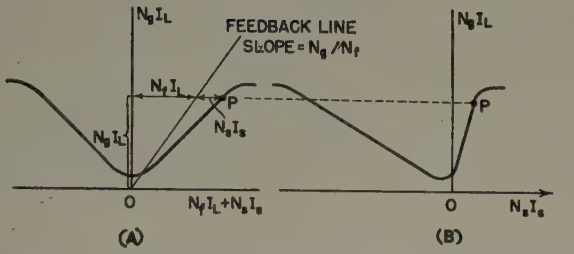


Figure 9. Derivation of the transfer curve with feedback

the amplifier is small. The half-power frequency of the control circuit is $1/2\pi t_c$. For a half-power frequency equal to only one-sixth of the supply frequency, the gain is down to about 4.

THE MAGNETIC AMPLIFIER WITH EXTERNAL FEEDBACK

The elementary magnetic amplifier displays two characteristics which are typical of devices that have large amounts of negative current feedback. First, the gain is not nearly as great as one might expect when using a magnetic material with such sharp saturation. Second, as the transfer characteristic of Figure 5*A* shows, the output current is independent of the load resistance over the working range. This inherent feedback effect is the basic reason for the limitations outlined in the preceding section, and it is commonly neutralized in one of two ways: either by rectifying the load current and using it to produce positive current feedback through a separate winding on the reactor, or by using a self-saturating circuit in which the neutralization is accomplished by means of rectifiers connected in series with the gate windings. The first method is illustrated in Figure 7. The load can be placed in either the d-c or the a-c side of the rectifiers.

The difference between the waveshapes in this circuit and those of Figure 4 is shown in Figure 8. The main difference is that the total "control" ampere turns on each core are now $N_fi_L+N_si_s$, where N_f is the number of feedback turns, N_s is the number of turns on what now will be designated as the "signal winding," i_L is the instantaneous load current, and i_s is the instantaneous signal current. The total control ampere turns are still approximately equal to the gate-winding ampere turns, but, since part of this is supplied by the feedback winding, only the small remainder must be supplied by the signal winding. On the basis of the areas in Figure 8*B*, the following can be written in terms of average values: Average control ampere turns$=N_fI_L+N_sI_s$, where I_s is the d-c component of the signal current.

This reasoning can be applied graphically to the transfer characteristic of Figure 6 in the manner shown in Figure 9, where the total control ampere turns are now designated as $N_fI_L+N_sI_s$. For small amounts of feedback it may be sufficiently accurate to use the idealized transfer characteristic of Figure 5*A;* for larger amounts of feedback one might use an experimental transfer characteristic or one calculated by more refined methods than were used in the preceding sections. In Figure 9*A*, a "feedback line" is drawn at a slope of N_g/N_f. If any point *P* is picked on the curve, then the ordinate is N_gI_L, and the abscissa to the feedback line is $(N_gI_L)(N_f/N_g)=N_fI_L$. The remainder of the horizontal distance to the point *P* therefore represents N_sI_s. Hence, if the graph of Figure 9*A* is skewed so that the feedback line becomes the new axis of ordinates as in Figure 9*B*, the result will be the transfer curve plotted against N_sI_s, which is the desired result. The ampere-turn ratio is now greater than unity on the right-hand branch of the curve. A bias winding can be added to the reactor to make the quiescent point fall where desired.

If N_f is made equal to N_g (100-per-cent feedback), the inherent negative feedback is entirely canceled and the transfer curve rises very steeply. A further increase in feedback may make the curve bend back over itself, thus producing a trigger action.

It will be observed that a 100-per-cent feedback line will produce meaningless results when applied to the idealized transfer characteristic of Figure 5*A*. The reason for this is that, with 100-per-cent feedback, the deviations from ideal behavior are the determining factors, and the actual details of the hysteresis loop must be taken into account. An analysis of all the pertinent effects is difficult and lengthy, and will not be attempted here.

THE ADVANTAGES OF FEEDBACK

The increase in slope of the transfer function by the use of feedback brings nonlinearities into greater

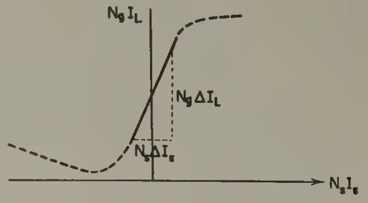


Figure 10. Section of actual transfer characteristic

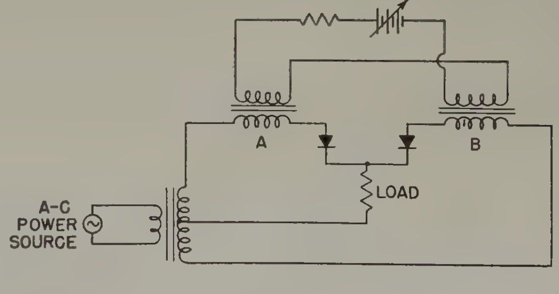


Figure 11. The full-wave self-saturating circuit with d-c output

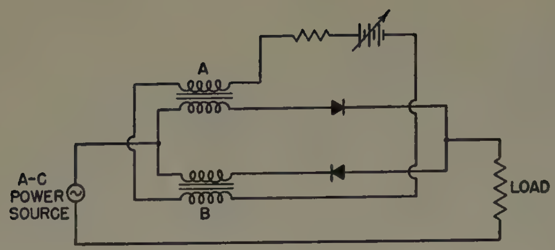


Figure 12. **The doubler self-saturating circuit with a-c output**

prominence, especially for large signals, and this forms a limitation on the advantages to be described. Assume that the ampere-turn ratio N_gI_L/N_sI_s has been increased from unity to the value m by the application of feedback. Since the quiescent current is not zero, a useful definition of power gain is (see Figure 10)

$$G=(\Delta I_L)^2R_L/(\Delta I_s)^2R_s \tag{12}$$

where R_s is the signal-circuit resistance.

Since, by definition of m, $N_g\Delta I_L=mN_s\Delta I_s$, this reduces to

$$G=m^2(R_L/R_s') \tag{13}$$

where R_s' is the signal-circuit resistance referred to the gate-winding turns, as indicated in equation 6. It will be observed that the gain goes up as m^2.

On the other hand, the inductance of the signal coil is given by $L_s=N_s(2\Delta\phi_0)\times10^{-8}/\Delta I_s$, and ΔI_s is reduced by the factor m. Therefore, the inductance is increased by the factor m, and, from equation 10,

$$t_c=mR_L/4fR_s' \tag{14}$$

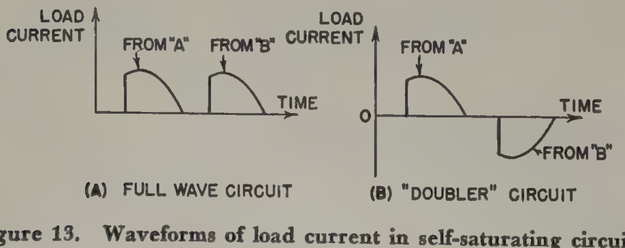
The time constant increases only linearly with m, and the ratio of gain to time constant is now

$$\frac{G}{t_c \text{ seconds}}=4mf \quad \text{or} \quad \frac{G}{\tau_c \text{ cycles}}=4m \tag{15}$$

This ratio is improved by the increase in m. Values of m equal to 100 or more are possible with good core materials without encountering excessive nonlinearity. The improvement can be split as desired between better gain and smaller time constant by adjusting the resistance of the signal circuit.

SELF-SATURATING CIRCUITS

The effect of 100-per-cent feedback can be accomplished more simply by the use of rectifiers connected in series with the gate windings of the reactor. There are a number of such circuits, and two of the more important ones are shown in Figures 11 and 12. The full-wave self-saturating circuit, shown in Figure 11, requires a center-tapped source, and provides a full-wave rectified output. The "doubler" circuit of Figure 12 provides an unrectified output. In both circuits, the two cores fire alternately on successive half-cycles, producing load currents of the form shown in Figure 13. When one core is firing, the other rectifier prevents a reverse current from flowing through the gate winding of the other core.



(A) FULL WAVE CIRCUIT

(B) "DOUBLER" CIRCUIT

Figure 13. **Waveforms of load current in self-saturating circuits**

The transfer characteristic for either circuit is essentially the same as that obtained by using a separate 100-per-cent feedback coil in the external-feedback circuit of Figure 7. In fact, in terms of circuit equations, the doubler circuit is completely equivalent to the external-feedback amplifier with $N_f=N_g$, and the full-wave circuit is equivalent to the external-feedback circuit with the load inserted on the d-c side of the rectifiers. For any of these circuits, the exact shape of the transfer characteristic is determined by the details of the hysteresis loop of the core material, and is adversely affected by a lack of sudden saturation, by hysteresis and eddy-current losses in the core, and also by rectifier leakage.

It is found that an inductive load will alter the transfer characteristics of the full-wave circuit by not permitting conduction to stop at the exact end of the half-cycle. The result is the same as that of additional feedback, sometimes even to the point of causing the transfer characteristic to bend back over itself, thus causing a trigger action. The difficulty can be diminished by the use of a rectifier or capacitor across the load.

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Steel Extrusion Process

Precise temperature control, accomplished by a complex electronic system developed by Minneapolis-Honeywell, is a vital factor in a new hot steel extrusion process.

In the new process, called "Ugine Sejournet" after its French inventor, hot billets of tough stainless steel are rammed through dies to produce tubes and shapes. Glass in various forms is melted by the process to act as a high-temperature lubricant. The new unit for the process consists of a 2,500-ton hydraulic press and related facilities all of which are instrumented and automatically controlled.

The slugs are first heated in a 3-zone gas-fired furnace which can produce temperatures up to 2,300 degrees Fahrenheit. The slug then is carried by conveyor to a barium-chloride salt bath which softens furnace scale and brings the steel billet up to final extruding temperature, about 2,200 degrees Fahrenheit, to make it plastic. Then, at the die, the steel is squeezed like toothpaste from a tube by the giant press into tubes and a variety of shapes.

To maintain control over temperatures throughout, the system employs a number of radiation devices which literally see the heat. These devices relay temperature information to a series of electronic recording and controlling instruments for automatic regulation of heat.

Arcing Time of High-Voltage Air-Break Contactors

C. A. LISTER
MEMBER AIEE

A HIGH-VOLTAGE AIR-BREAK contactor must be able to interrupt the circuit to motor loads or static loads covering a wide current range. Considerable attention has been given to the ability of contactors to interrupt fault currents, but little has been published on the problem of obtaining satisfactory performance at low currents. The difficulty at low currents is one of getting acceptably short arcing time.

It has been pointed out previously that for low power factor static loads the arcing time at low currents is relatively long.[1,2] Some tests on motor loads have shown very short arcing time for low currents, and it may be that there is no danger of excessively long times with such loads.[1] However, to make application simple, it is desirable to design a contactor with acceptably short arcing time at low currents, regardless of the type of load, provided, of course, that fault-interrupting ability is not sacrificed. This article considers some of the factors which affect the low-current arcing time of high-voltage air-break contactors.

Examination of the interruption process employed in high-voltage air-break contactors will show the reason for the relatively long arcing times at low currents. Figure 1 shows those parts of a typical contactor which are involved in the interruption process. In operation an arc is drawn between contact tips and is forced onto and up arc runners by a transverse magnetic field set up by a series-excited blowout. As the arc is forced into contact with cooling plates, it is deionized and extinguished. At low current the blowout field is weak so that the arc travels at a relatively low velocity and consequently the arcing time is long.

Two factors which affect the arcing times of contactors are evident, the strength of the blowout and the position of the cooling plates. In order to determine the relative importance of these factors, an experimental study was undertaken in which low-current arcing times of static loads were measured using blowout coils having 1 to 32 turns and with the cooling plates placed successively in the five positions shown in Figure 1.

For the 10- to 40-ampere current range considered, arcing time varied approximately as a small negative power, -0.25 to -0.35, of the blowout flux density and as the minus one power of distance between contact tips and cooling plates. Arc velocity measured along the shortest line between tips and cooling plates was constant for a given value of the product "Blowout Flux Density times Current" and varied nearly as a small power of this product. Arc velocity along parallel arc runners was higher than along runners which diverged.

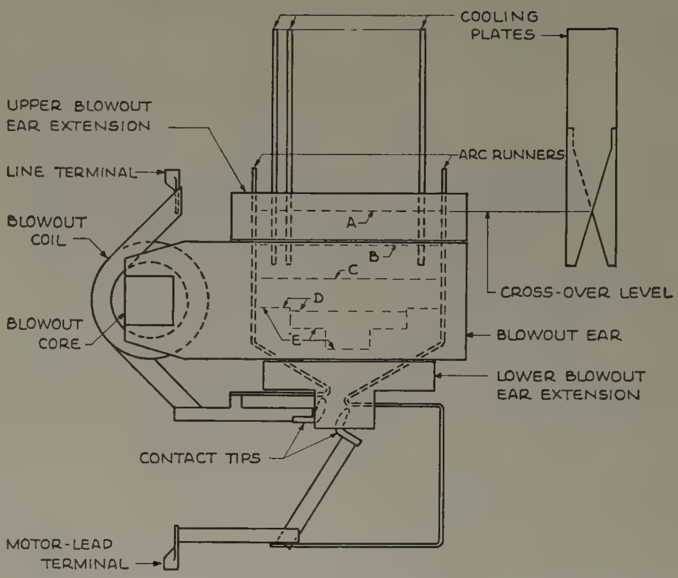

Figure 1. Schematic diagram of high-voltage contactor. Dashed lines A-E show crossover levels for various positions of cooling plates

When the current to be interrupted was made sufficiently small, a large percentage of interruptions occurred without the arc transferring to the arc runners and with an arcing time of less than 1 cycle. This effect appeared more pronounced at higher tip opening velocity.

While the character of load handled by a contactor is not subject to control by the contactor designer, it is useful to know the effect of the type of load on arcing time. Tests on static loads in which the power factor was varied showed that as the power factor was increased for a fixed and sufficiently small current, the percentage of interruptions which occurred without arc transfer increased, but for those interruptions in which arc transfer did occur the arcing time was independent of the power factor. No motor loads were used in the tests, but it has been pointed out by others that with motor loads, counterelectromotive force reduces the recovery voltage across the tips thereby making interruption simpler. It is believed that the fast interruptions of motor loads which have been reported previously[1] were of the same type as the interruptions noted here without arc transfer. In such cases the arcs are broken on the contact tips, the blowout field and cooling plates not taking part in the interruption.

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EDVAC Drum Memory Phase System of Magnetic Recording

DONALD EADIE

The three principal aspects of the read-recording system used for the magnetic drum memory of the EDVAC are described in some detail. These are the general recording method, the component parts of the system, and the general over-all system of recording and reading back the information recorded.

THE Electronic Discrete Variable Computer's (EDVAC's) present high-speed internal memory[1,2] is of the sonic delay type and consists of 128 mercury tanks. Eight words, in sequence, are continuously circulated in each tank and these can be erased, replaced, or transferred according to orders transmitted by the EDVAC's dispatcher.* This memory, although adequate in the light of original requirements, has since proved insufficient; hence, the development and addition of an intermediate-speed high-capacity memory long has been the aim of members of the Computing Laboratory staff.

Magnetic recording on a drum is especially advantageous for an intermediate-speed memory not only from the viewpoint of access time, but also for compactness (as only a small space is required to store information), and because the information recorded is retained and can be recovered in the event of a power failure. Although access time is not in the order of microseconds, as is the case with the high-speed internal memory, still it is fast enough so that the computer spends little time waiting for a search to be carried through. It is possible to transfer stored information automatically from the drum to the internal memory and conversely during a computation.

Although it is not necessary, flow generally will be in blocks of eight words or more and computation time should not be affected adversely by the access time limitation of 20 milliseconds required by the magnetic drum. However, the EDVAC is designed so that the numbers or orders used at a particular time must be routed from the internal high-speed memory. Therefore, information recorded on the drum must be inserted first into the internal high-speed memory before it can be used in computation.

In the EDVAC a typical *number* word, for example, has 43 binary digit positions assigned to represent the decimal digits of a number. Also a single binary digit position occurs previous to the least significant binary number digit and is used to indicate the sign of the number. Consequently, in a particular word, 44 binary digits occur in time sequence, one digit following the next by 1 microsecond in time—the sign digit occurring first, followed by the 2^{-43} digit, the 2^{-42} digit, and so forth, in that order. Because of this pulse-time relationship, the EDVAC is classified as a serial-type digital computer.

Instead of 44 microseconds, however, a single word as circulated in the EDVAC and stored in an internal mercury tank memory actually occupies 48 microseconds. The 4 additional microseconds are added so that a time interval between words is provided during which switching of control circuitry can be accomplished. These four pulse positions are known as the switching blank.

In all, the present high-speed internal memory of the EDVAC has a storage capacity of 1,024 words and the drum will increase this present memory capacity by approximately an additional 10,000 words.

It became quite apparent early in the development that the read-recording system used with the drum must have the following characteristics:

1. The system evolved must store both *1*'s and *0*'s.
2. It must accept and release number word information at a 1-megacycle rate (1 pulse per microsecond).
3. It must be reliable and always synchronized to the EDVAC—that is, a specific timing relationship must always exist between a particular EDVAC pulse and the position it is to occupy in storage on the drum.
4. The recording of new information over old information must automatically cancel the old information. All systems considered were of this type; hence, no erasure is needed—the magnetic surface being sensitive to the polarity of the last pulse recorded at that point.

The magnetic drum–EDVAC synchronizing is accomplished by a servo-system which compares pulses generated by a photocell scanning a synchronizing wheel attached to the rotating drum to pulses generated in the EDVAC. This system holds the drum in step with sufficient precision so that word information can be read to or from the drum directly into or out of the EDVAC without the necessity of any time-conversion equipment or shift registers.[2]

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* Unit of the EDVAC which controls the automatic operation of the computer.

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The development of the system was carried out by the Computer Research Group of the Computing Laboratory, Ballistic Research Laboratories (BRL), Aberdeen, Md. A portion of the circuitry used was based on suggestions originally proposed by R. L. Snyder, T. C. Hill, R. V. Gorman, and other members of the BRL staff whose knowledge and advice contributed largely to the success of the over-all system. The drum and recording heads were developed by the Brush Development Company, Cleveland, Ohio.

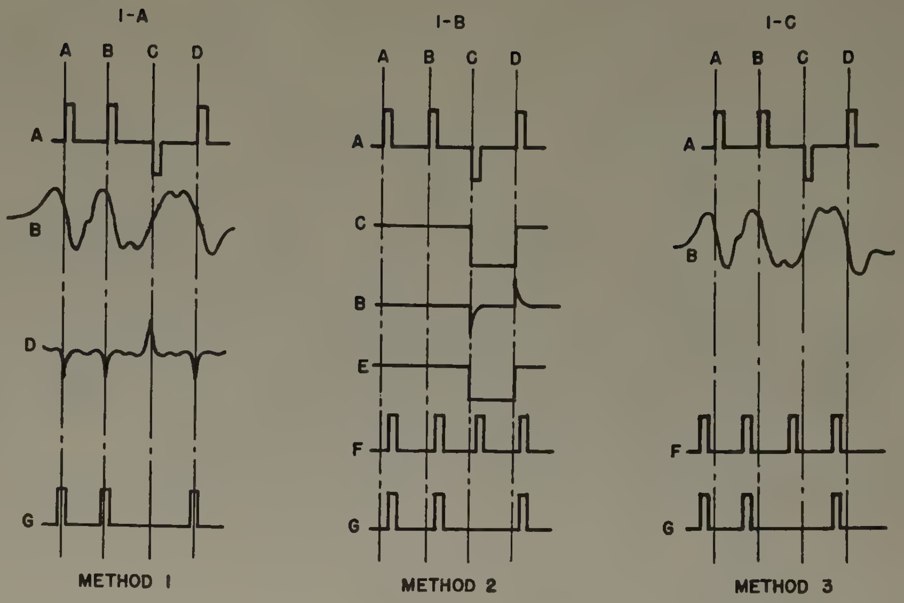

Figure 1 (right). Usual methods of recording and recovering digital information

A—Recorded pulse sequence; B—Recording head output; C—Recorded flux; D—Differentiated readback pulses; E—Gating flip-flop; F—Clock pulses; G—Output pulses

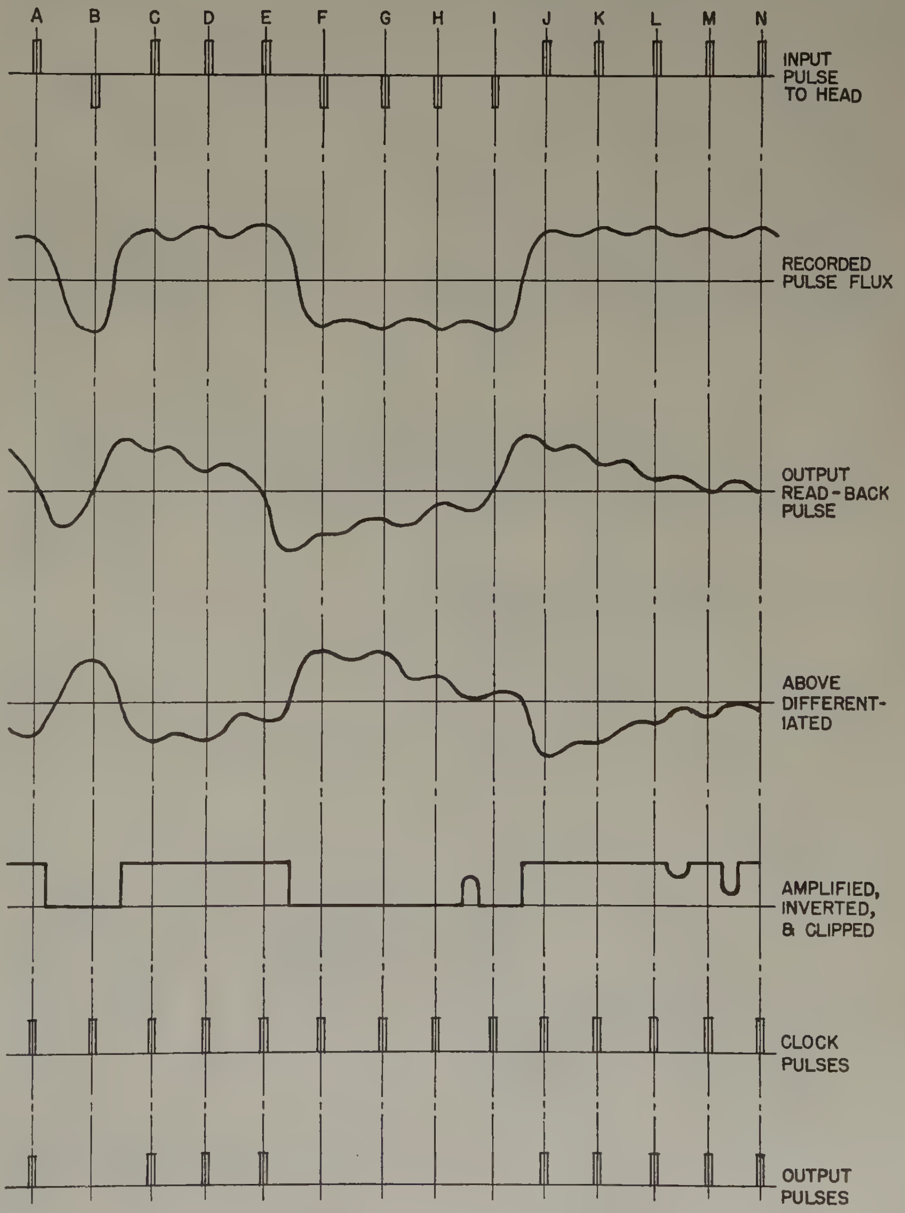

Figure 2 (right, below). Typical pulses occurring in one channel of Method 4

RECORDING SYSTEM

In the EDVAC drum system, six heads are used in the recording or reading of any single word. Because each word follows the previous one directly on the surface of the 18-inch-long 12-inch-diameter drum, as many as 384 words can be recorded in sequence on one band.† Twenty-five such bands are used; consequently, 150 recording heads are required—six heads to a band. The six heads allotted to a particular band are switched by double-throw 6-channel relays. Twenty-seven such relays are arranged in a relay tree in order that the six parallel read amplifiers or the six parallel record amplifiers are connected (depending on whether the read or record cycle is called for) to the head of the band concerned. These relays are tube-controlled and are set up before any recording or reading is attempted. Another separate 6-channel double-throw relay is used to determine the direction of the routing—that is, whether the information is to travel from the heads to the *read amplifiers* or from the *record amplifiers* to the heads. The same heads are used for both reading and recording, one side being grounded and the other side being connected through the band selection relays mentioned.

When the system was first planned, 80 pulses per inch seemed to be about the accepted maximum number of binary digits that could be recorded safely, although recent papers[3] have pointed to drums using considerably denser packings. Head spacing in the EDVAC drum case is such as to give ten tracks per inch laterally.

Rotating the drum at 3,254 rpm and using a packing density

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† This refers to the group of six tracks that are linked to the six *read* or *recording* amplifiers for a particular setting of the band selection relays.

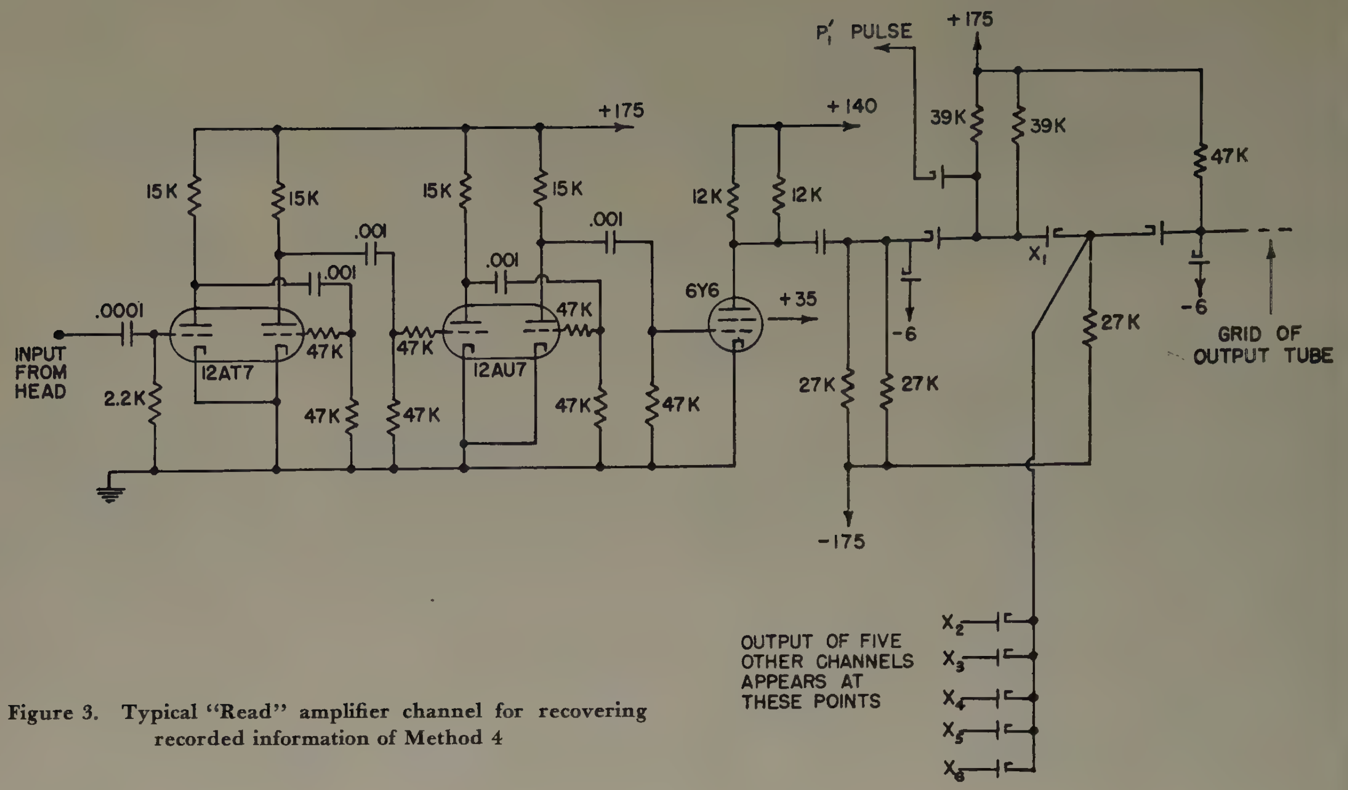

Figure 3. Typical "Read" amplifier channel for recovering recorded information of Method 4

of 80 pulses per inch gives a frequency response required of the heads of approximately 166 kc per second. Hence, in order to record at a megacycle rate it is necessary to stagger the pulses and record on six heads, as mentioned. The first and seventh pulses are recorded on the first head, the second and eighth on the second head, and so forth. A switching circuit, which is known here as a P-Prime Generator, is used to cycle the heads and enable the word pulses to be distributed in an orderly sequential manner between the six heads. By this system an individual head need respond only to 166 kc. However, as pointed out previously, six parallel separate channels for both reading and recording are required in addition to the pulse cycling circuit mentioned.

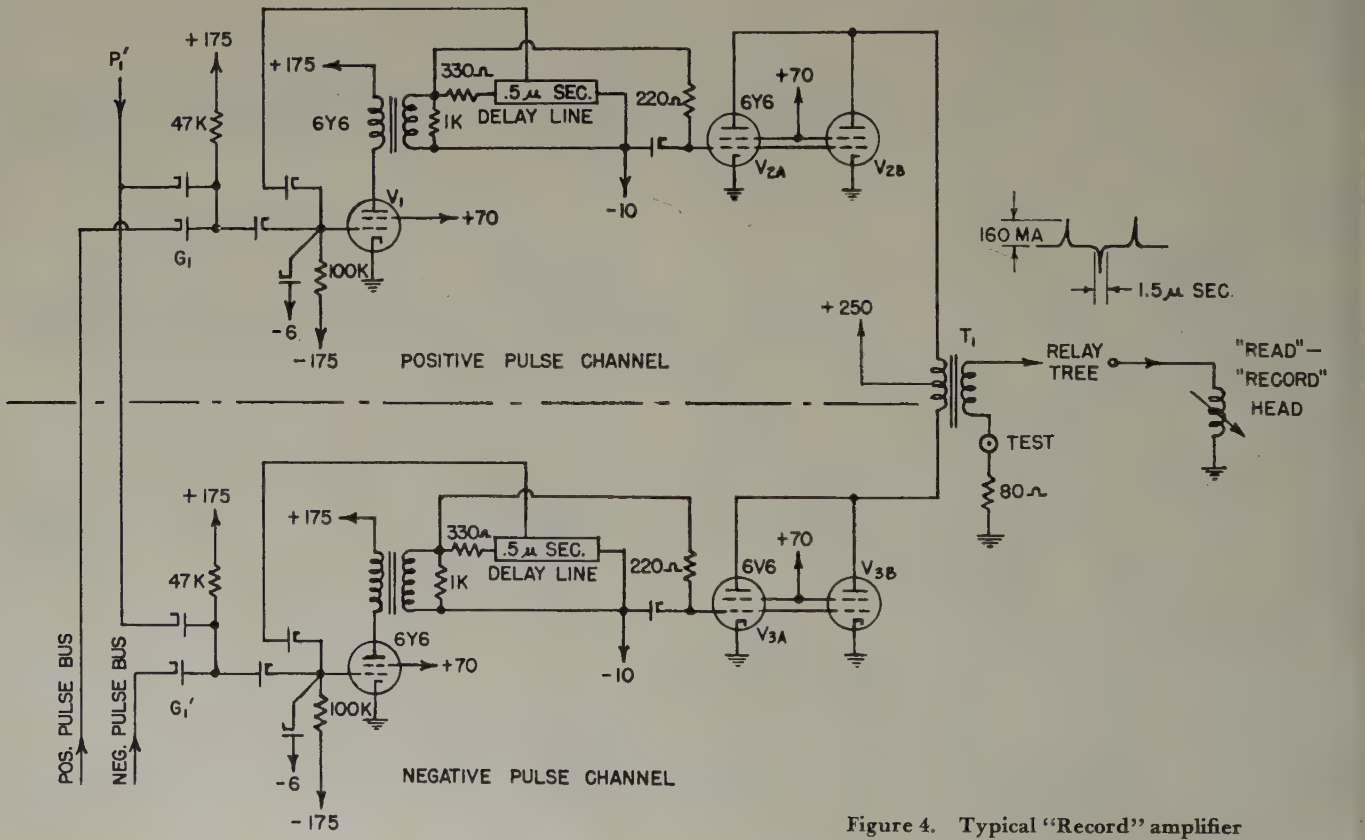

Figure 4. Typical "Record" amplifier

PHASE RECORDING

When faced with the problem of recording several pulses both positive and negative and one following the next, there are three general methods to consider.

Method 1: Where the pulses are spaced sufficiently so that conventional differentiating or integrating techniques will restore the original pulse shape (see Figure 1*A*).

Pulse *C* on readback need not be recovered because of the fact that negative pulses represent the absence of a pulse in that particular word position. For this reason, in Figures 1*A*, 1*B*, 1*C*, and 2 the negative readback pulses are eliminated in the final shaped output.

Method 2: Where positive or negative direct current is recorded and only the transition from positive to negative (or conversely) is recognized by the head (see Figure 1*B*). This transition sets a flip-flop operating the pulse gates.[4]

Method 3: Where clocking pulses are used to check the position of the positive portion of the recorded wave (Figure 1*C*).

After due consideration it was decided to adopt a system (Method 4) that was essentially a combination of the three.

First of all, the pulses are recorded so close together in Method 4 that the flux left in the surface for a string of like polarity pulses is essentially of one polarity as in Method 3, and on readback the head tends to recognize only the transient condition existing when the polarity changes. However, a ripple component is recorded also and this, too, can be recognized and read by the head. It is to be noted that the phase of this ripple for a string of (+) pulses differs 180 degrees from the phase of ripple for a string of (−) pulses. Even though pulses are alternating in polarity this phase relationship still exists. The amplitude transient on readback, at a point where a string changes from (+) to (−) or conversely is, as pointed out in the foregoing, considerably larger than the ripple mentioned and could be used to set flip-flops in the same manner as is done in Method 3.

In the Phase System, however, the readback signal from the head is first differentiated, then amplified and clipped. After this final shaping, clocking pulses are injected along with the shaped signal into a positive *and* gate with the result that the original information recorded in the channel is recovered.

CIRCUITS

An amplifier (only one channel of six shown) for recovering recorded information of Method 4 occurs in Figure 3; waveforms obtained at the output of the *and* gate are those of Figure 2. The output of this channel amplifier is added to the outputs of the five other identical ones in the *or* gate whose inputs are indicated as X_1 through X_6 in Figure 3.

The pulse amplifier for recording is illustrated in Figure 4. Here a delay line is used to widen the incoming signal pulse to 1 microsecond by feeding back a positive pulse to the grid of V_1. The negative reflection from the short-circuited delay line cancels the positive regenerative signal at a time twice the length of the 0.5-microsecond line. The widened pulse is fed to V_{2A} and V_{2B} where it is amplified and applied to the recording head via T_1. A negative pulse is obtained by pulsing a similar channel but in this case T_1 is pulsed by the current flowing in the plate circuit of V_{3A} and V_{3B}.

The P-Prime Generator (Figure 5), the device for generating pulses used to cycle the record and read amplifiers, functions as follows:

Clock or timing pulses are generated in the EDVAC at a rate of one per microsecond. Essentially all that is done is to allow one clock pulse to travel down a delay

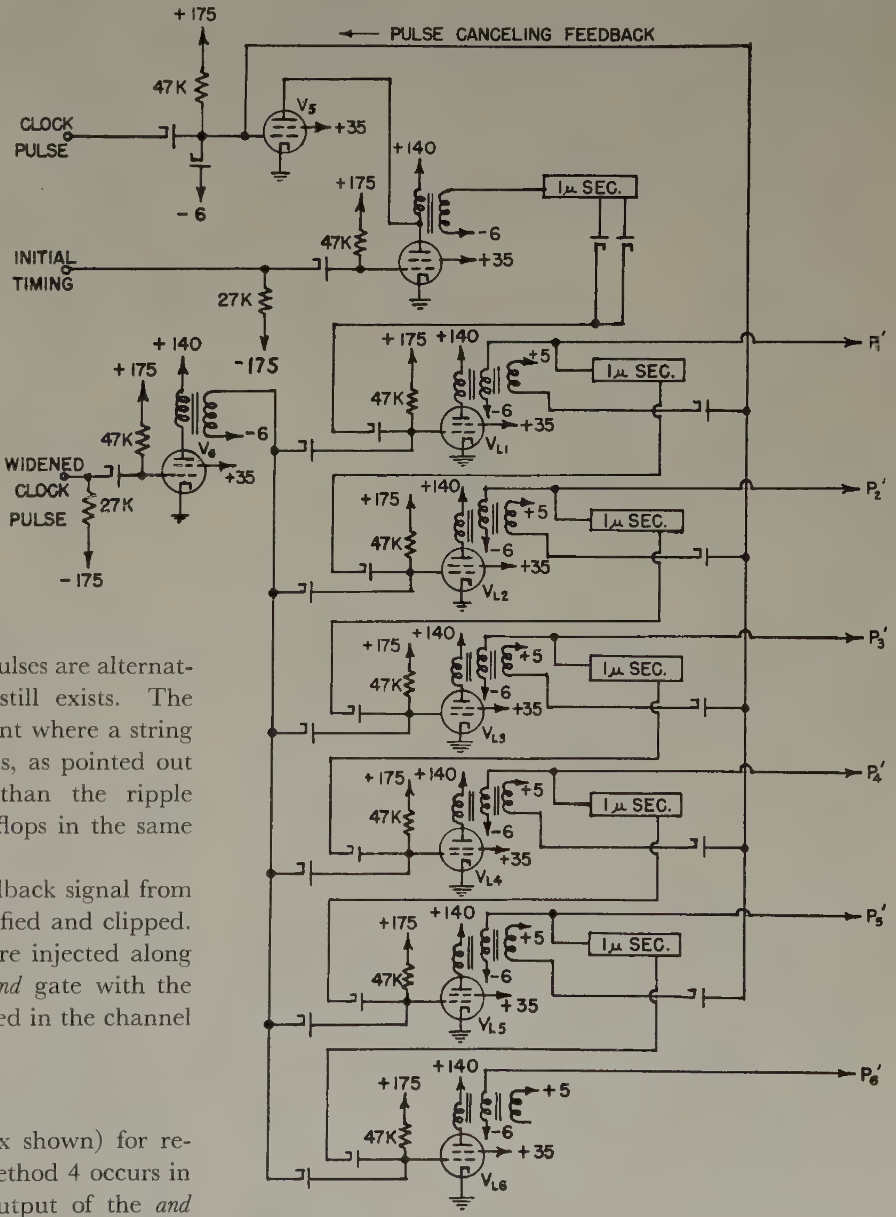

Figure 5. P-Prime generator

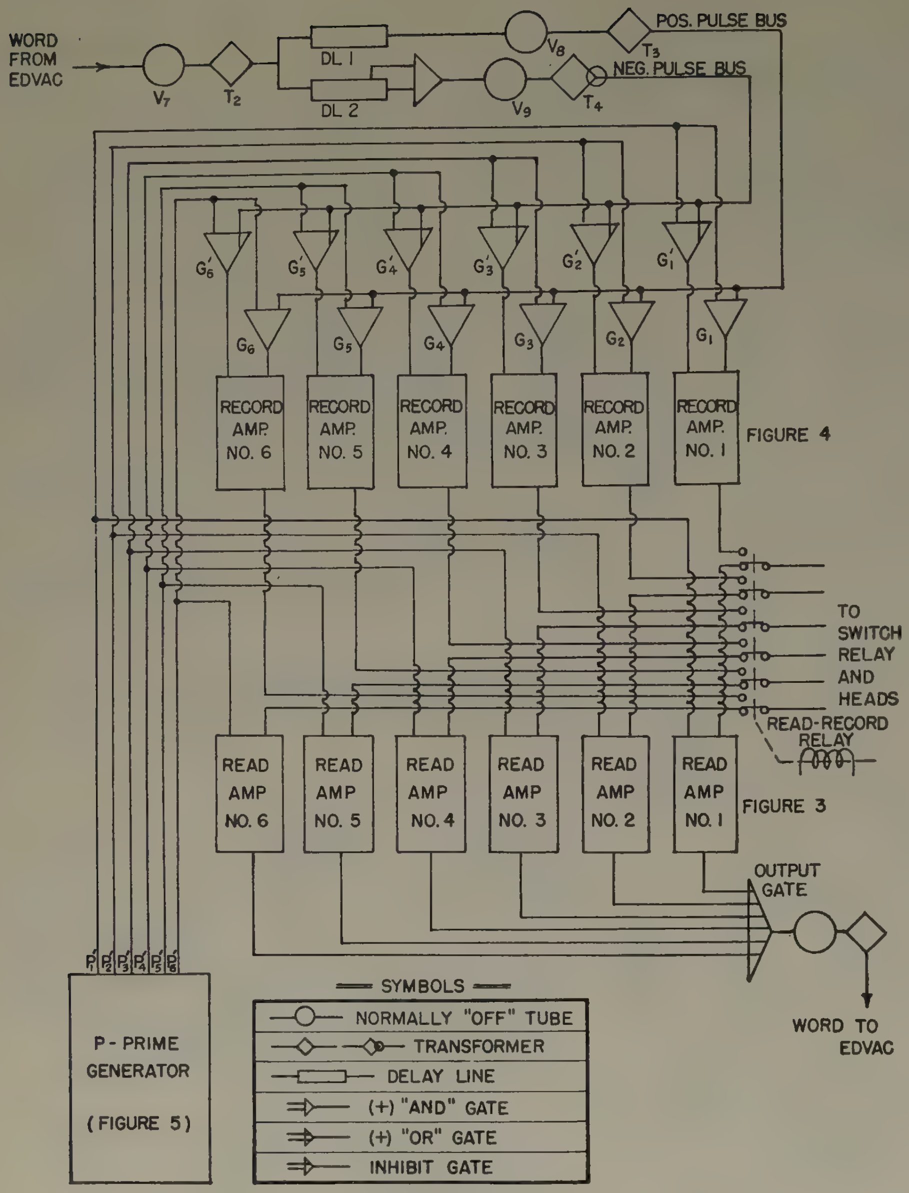

Figure 6 (left). "Read"—"Record": the complete system to read-record relay

line and at 1-microsecond intervals pulses are fed back to the input in such a way as to cancel the existing clock pulse at that moment. In the unit used for the EDVAC magnetic drum five pulses are fed back; hence, *P*-pulses *1*, *7*, *13*, *19*, *25*, *31*, *37*, and *43* only travel down the line.

The line is not a continuous 6-microsecond delay line but is broken at the 1-microsecond points. A tube and transformer are inserted at these points so that:

1. A pulse may be extracted for application to the *read* and *record* amplifier input gates.
2. Clocking pulses may be applied to the input grid of tubes V_{L1} through V_{L6} so that the pulse traveling down the section of the line following the tube can be kept narrowed to a particular width.
3. A solid drive is provided; hence, satisfactory pulses are assured for the input gates of the read and record amplifiers.
4. Transformers provide a convenient means of inverting polarity for feedback to the input *or* gate of the P-Prime Generator where pulses P_2 through P_6 are eliminated from the delay line.

Tube V_6 is the driving tube for the first section of delay line and is in parallel with the tube which determines the initial pulse that proceeds down the delay line establishing the correct timing.

THE COMPLETE SYSTEM (Figure 6)

THE PULSES OF a word to be recorded are amplified by V_7 and appear on the primary of T_2. T_2 has two secondaries, each of which drives a delay line. *DL 1* delays the pulses to V_8 and T_3 such that these pulses will fall in the middle of the widened pulses generated by *DL 2* supplying the grid of V_9 and eventually T_4. Pulses from T_3 drive the common bus supplying G_1, G_2, G_3, G_4, G_5, and G_6 while pulses from T_4 are inverted and similarly drive G_1', G_2', G_3', G_4', G_5', and G_6'. These latter pulses are negative inhibit pulses.

Pulse P_1' from the P-Prime Generator appears at the input gate G_1 and G_1' of record amplifier number *1* at the time of *P* Pulse P_1, P_7, P_{13}, and so forth. P_2' appears at the input gates G_2 and G_2' of record amplifier number *2* at the time of the *P* Pulse, P_2, P_8, P_{14}, and so forth. The same process occurs with the remainder of the P' pulses and *P* pulses.

Since all these amplifier input gates are coincident-type *and* gates, the P' pulses effectively determine which amplifier will accept a particular *P* pulse of the order. The *P* pulses appear in parallel as positive pulses on the inputs of the gates G_1, G_2, G_3, G_4, G_5, and G_6, and as negative pulses on the inputs of G_1', G_2', G_3', G_4', G_5', and G_6'. Coincidence can occur on G_1 only between Pulses P_1, P_7, P_{13}, and so forth, of the number word at the time of P_1'. On G_2 the coincidence is confined to P_2, P_8, P_{14}, and so forth, and P_2'. The same sequencing and sorting continues at G_3, G_4, G_5, and G_6 between the associated P' pulses and the particular *P* pulses that fall in coincidence at a particular gate. The negative channel is inhibited during each foregoing case by the output of T_4.

If a blank occurs in the number word, no *P* pulse will appear on the common bus feeding G_1, G_2, G_3, G_4, G_5, G_6. However, the P' pulse is not inhibited on the input of G_1', G_2', G_3', G_4', G_5', or G_6', whichever gate is involved at the time of this blank. For instance, assume that at time P_1 no pulse occurred in the number word being recorded. Then no positive pulse would have appeared at the input grid of V_8 of the positive channel of record amplifier number *1* and since there was no coincidence here—and no inhibit pulse on Gate G_1'—a P_1' pulse proceeds through the negative channel of record amplifier number *1* and records a negative pulse on the drum. The same type of operation again holds for all six channels.

During readback all six read amplifiers are functioning up to the output *or* gate continuously. However, before this point the individual amplifiers are sampled again by P' pulses as pointed out in the circuit section; hence, the combined pulse outputs will consist of the individual pulses restored to their proper order in the number word being transmitted back to the EDVAC's internal memory.

SUMMARY

In order to record and read the information so that it would fall into place in time sequence with the EDVAC, it has been necessary to employ a high-precision positional servo to hold the drum in correct relative position and to employ standard digital coincident techniques to insure that the pulses recorded are stored in a position that can be scanned in the same sequence on readback. Because the packing density was limited to 80 pulses per inch at the drum rotational speed employed, in order to read and record pulses at a 1-megacycle rate, it is feasible to accomplish this splitting and gathering by comparing the output of the P-Prime Generator with the word digits to be read or recorded in coincident *and* gates. Parallel channels for both reading and recording are used from the point where the word is split up among the six record amplifiers until it is restored to normal form on readback at the combined output of the six read amplifiers. A relay tree switched by flip-flops connects the six heads at the particular band in use to the inputs of the read or record amplifiers depending, of course, on the required direction of information flow.

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Integration Versus Options in Electrical Engineering

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FELLOW AIEE

With the growth of electrical engineering and the introduction of options in engineering education, the electric power field lost much of its popularity with students to the more glamorous communications and electronics curricula. To compensate for this trend, the universities must establish a creative environment for study of energy conversion and utilization subjects.

From the birth of electrical engineering up to about the end of the first quarter of this century the primary concern of most electrical engineers was to provide society with systems for the generation and distribution of electric energy. Great power stations were designed and constructed. Motors, switchgear, protective devices, and the like were developed to a high degree and were used to drive the industries of the day. Throughout the period much of the activity of the departments of electrical engineering within the universities and technical colleges of the United States was focused on the training of young men for this work. Thus there emerged the great professional field which subsequently was called electric power.

The last 2 decades have witnessed the appearance of several new fields within electrical engineering. By the late '30's the field of communications had reached a degree of maturity that gave it a status substantially equal to that of the field of power. By the late '40's it had become the senior partner of the team. Many schools recognized this situation by establishing both electric power and communications options. Some even added a third option on electronics. More recently, feedback-control system engineering has become a field of its own staffed largely by electrical engineers.

THE PROBLEM OF OPTIONS

A glance into the future indicates that the growth of electrical engineering is not over. There are indications that the kinds of activity that employ electrical graduates are becoming more and more numerous as the years go by. As a consequence, universities and technical colleges are today coping with an ever-expanding problem of what to regard as appropriate curriculum substance, and what to do about course options, in the face of a strong desire to hold to the 4-year program for the bachelor's degree.

That the problem of options is squarely before us is evidenced by the fact that within the larger schools there is a serious unbalance in the degree of on-campus enthusiasm and creativity on the part of both staff and students

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Substance of an address presented at the Conference on Education held during the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953, and recommended for publication by the AIEE Committee on Education.

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in the power field in comparison with that observed in the electronics field. The latter field is everywhere flourishing. This, in part, may be attributed to the fact that much glamour is associated with such topics as radio, television, computers, and so forth. Students are biased toward the electronics field even at precollege age. Furthermore, colleges find it relatively easy to offer their faculties unlimited opportunities for creative on-campus work in these areas. They thus can attract and hold top-flight men. This, in turn, attracts top-flight students. Finally, the substance of an electronics curriculum is such that it is easy to make the teaching program creative at the student level.

The situation in the field of electric power is almost the exact opposite. Modern instruction in much of the power area is rarely of a kind that can be called creative even by the students. Most of the facilities for the power groups are old, and, by comparison with electronics, are ponderous. Industry and educational institutions have both failed to retard the persistent atrophy of on-campus research, with the result that an essential ingredient of a good educational program in the field of electric power is almost wholly nonexistent. This withering away is so persistent that there is today widespread concern among electrical engineering educators[1] and the leaders of the large industrial corporations over the fact that the electric power option is not attracting students in sufficient numbers nor of adequate intellectual ability to meet the demonstrated needs of the times. The question as to whether many schools should continue to allocate plant and faculty to support this field has been seriously asked. But it seems out of the question to discontinue a program of instruction which trains students to enter the power field if the rapid growth in the generation and utilization of electric power in the immediate past and the indicated growth in the years ahead are a reliable index.

It is not sufficient merely to brush aside this problem with the statement that the colleges should abandon options, teach only fundamentals, and let industry take care of the specialties. To do this would relegate to the engineering faculties the sterile task of replaying the same tune year after year. If this were all that a college should do, alive and creative faculties hardly would be necessary, for electrical engineering itself has made available systems for the reproduction of sight and sound that are fully competent to take over the function of a routine expositor. As Professor B. L. Goodlet indicated in an address before the South African Institute of Electrical Engineers,[2] the function of a university is not merely to teach the known facts of the day; in addition, it should sponsor and nourish creative thought of a kind that will yield the knowledge that will dominate a decade or so hence. Thus a university must concern itself with frontiers of knowledge. An educational program that is creative therefore must make students aware of frontiers. Because of the breadth of modern engineering and the limitations of men, this situation inherently calls for specialists.

THE BASIC GOALS

With the foregoing details as background, the question of options will be reviewed in the light of the major motivations of present-day electrical engineers. There appear to be but two such motivations. The first stems from the natural desire of men to process or to transmit information. It is this goal that motivates the people who work in the fields of communications, radar, television, computation, instrumentation, measurement, and even control. Everywhere one notes the pent-up enthusiasm of the majority of the workers in the field and the high level of creativity found in their accomplishments. The field is generously manned by able abstract thinkers who cast over it an umbrella of sound scientific thought under which engineers exploit the whole core of electrical technology, including electric energy conversion. The energy, however, is usually regarded as merely a means to an end and not as an end in itself.

The second motivation stems from man's desire to exploit energy for energy's sake. The engineers who power the great process industries of this country, such as chemical, steel, and manufacturing, are motivated toward this goal. The field is much broader than the so-called field of power, being more aptly classified as the "conversion, control, and utilization of energy." Its technical substance stems from the same brands of circuit theory, mathematics, physics, electronics, and so forth, as does the field of information processing. Differences if any are in relative emphasis —a matter of degree, not kind. Thus, if there must be options in electrical engineering, let us think of them in terms of these motivations, namely, on the one hand, *information processing*, and on the other hand, *energy conversion, control, and utilization.*

To reverse the trends in the electric power field the universities must broaden the base of scientific substance in the field and upgrade it professionally and in abstract scientific thought. The bold creative exploitation of energy-conversion and energy-utilization techniques must be encouraged in order that the expansion of one of the key elements in our economy can be continued.

The problem before electrical engineering educators can be tackled by first establishing a creative on-campus environment in the core subject of this area, the one commonly called electric machinery. At the birth of electrical engineering it was substantially all there was. It has received most of its intellectual nourishment from the power group. It is concerned primarily with the exploitation of electric charges and their attendant magnetic and electric fields to the conversion, transmission, and utilization of energy. As electrical engineering continued to grow, the able abstract thinkers gave their attention to new fields with the result that the subject became stereotyped. It ceased to be creative.

Because of the availability of conventional machines, most institutions established great dynamo machinery laboratories. While the laboratories comprise diversity of type such as shunt, series, and compound-wound d-c machines, and induction or synchronous a-c machines, each machine comes to the student "all growed up," so to speak. For the most part students spend their time analyzing existing designs. The equipment is so ponderous that a student cannot be expected to create a device of this kind during his student career. While the more able students realize that there are subtleties such as nonlinearities, that not all motors need rotate, they are rarely made to realize that the motor is merely the result of an engineer's effort to exploit the properties of materials as field-forming members in a dynamic energy system. It is rarely pointed out to them that engineering is the exploitation of modern science to the satisfaction of man's wants using the materials of nature. They seldom are asked how the machine got this way and the thought thereby raised in their minds that perhaps, if they start from the concepts learned in physics, they may devise other combinations to accomplish more useful ends. It almost looks as though educators deliberately try to isolate students from the scientific frontier in this area.

In contrast with this situation, observe the tempo in communications or electronics. Creative systems thinking is readily within the capacity of the student. A few vacuum tubes, sockets, resistors, capacitors, and a soldering iron permit him to synthesize systems that can perform many useful functions. The answer to the machinery problem, and in turn the whole field of energy conversion, is to establish it as a creative field, to replace traditional courses by something different. As a step toward this end, it is proposed at the Massachusetts Institute of Technology gradually to subordinate the existing machinery subject and replace it by a subject called "Control and Conversion of Energy." This new subject will deal with magnetic, dielectric, and conducting materials, with the importance of materials in industry, and will aim to show a student how engineers exploit the properties of materials in a creative way in the solution of broad engineering problems. Much new work on magnetic and dielectric amplifiers and transducers will be introduced. The treatment of components in the steady state will be subordinated to a treatment of the dynamics of energy conversion at the systems level.

Much of the traditional instruction in machinery analysis will have to be discontinued. A whole new concept for laboratory instruction on energy conversion devices and systems must emerge if the goal is to be achieved. Much of the equipment in existing electric machinery laboratories is inadequate and even a deterrent to progress in instruction. Much new equipment will be needed, and it should be explicitly of a kind that is as flexible at the student level as is the laboratory equipment for electronics subjects. The physical size of devices must be reduced, and more of it must be expendable in a student's own project.

THE SCHOOLS' RESPONSIBILITY

These arguments in support of upgrading the so-called electric power field in vigor and creativity should not be construed as a plea for options. For practical reasons, however, an activity needs some identity of its own if it is to be successful. Considering the unending expanse of electrical engineering and the degree to which mid-20th century science is coupled with engineering, it seems unwise to establish curricula options within a department. There is a grave danger of having guided a student into a narrow specialty and then failing to support him. The phenomenon of technical obsolescence is a great hazard. Creative engineering endeavor, however, is a powerful force. It constantly advances the frontiers of opportunity. Intensive training of engineers in depth in the sciences in a creative environment[3] that is truly representative of the breadth of engineering seems highly desirable. Every electrical student should appreciate the importance and the challenge in the area of control and conversion of energy as well as in the area of information processing—and the colleges and universities should measure up to their responsibility to make it possible for him to do this.

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Tachometer Generator Aids in Accurate Oil Well Surveying

A General Electric tachometer generator used in conjunction with electronic equipment is aiding the Schlumberger Well Surveying Corporation, Houston, Tex., in accurate recording of the characteristics of subsurface geological formations encountered in oil well drilling. The instrument enables Schlumberger well surveyors to read and maintain a more uniform speed while lowering or withdrawing instrument-bearing cables in the drill holes.

To utilize the tachometer, Schlumberger engineers pass the test cable over a wheel located at the rear of the survey truck. The shaft leading to the tachometer generator from the wheel imposes a motivating force on the generator which causes it to produce a voltage proportional to the speed of the cable passing over it. This voltage is directed then to the tachometer which interpolates it in feet per hour.

Control section of the truck which uses an industrial tachometer to measure precise depths and speed of cable being lowered in oil well surveying. Cable enters test hole in background

Transient Performance of D-C Machinery—I

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PREVIOUS STUDIES HAVE STRESSED the need for more accuracy in the calculation of transient currents than is provided by present methods. For the design of shipboard power systems, these methods are not sufficiently accurate and do not adequately reflect the influence of initial conditions of load, voltage, and speed on peak currents. There was also a disappointing lack of experimental verification of the important assumptions upon which the theoreticians were proceeding. Before developing a new approach or following a published calculation, it becomes evident that the limitations of any relations are determined by the validity and accuracy of the assumptions employed. It is concluded from this work that a more fundamental knowledge of the internal phenomena of rotating machinery is required before developing relations describing transient response of a d-c machine within design accuracy. Flux variations are fundamental to machine behavior in that they govern generated voltage, leakage fluxes, commutation, coefficients of induction, and eddy currents.

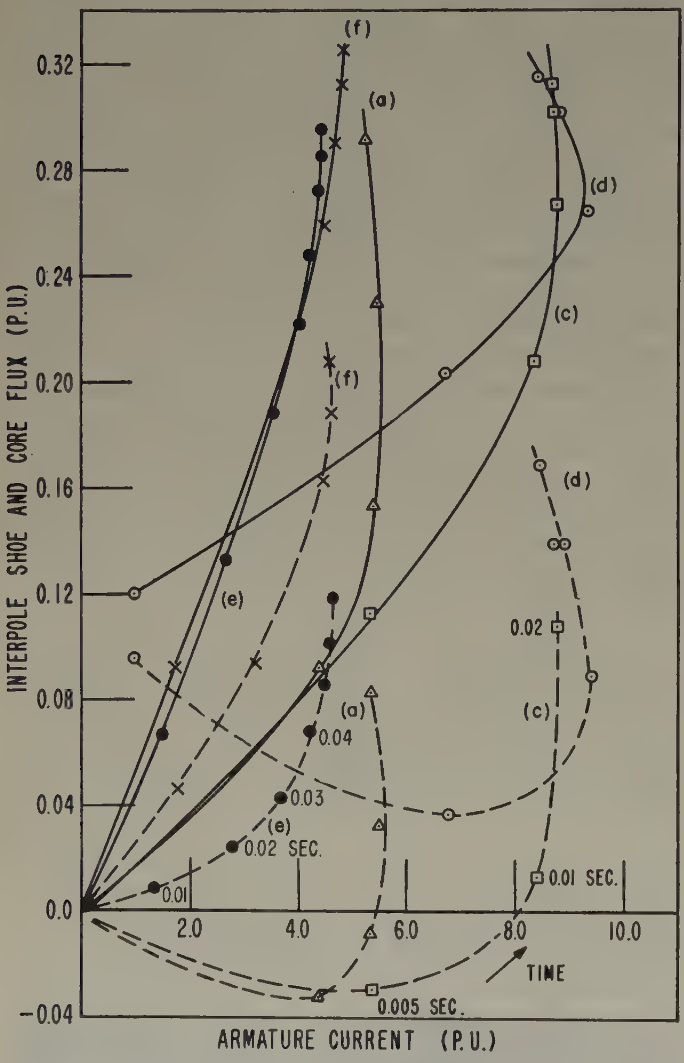

Figure 1. Comparison of interpole shoe and core flux during short-circuit tests to transient armature current. Conditions: differential series field connection; time, a variable along the curves

(*a*) *No load; 0.10 ohm short circuit*
(*c*) *No load; 0.001 ohm short circuit*
(*d*) *Full load; 0.001 ohm short circuit*
(*e*) *Brushes on neutral; blocked rotor*
(*f*) *Brushes shifted three segments; blocked rotor*
Solid curves—interpole core; dashed curves—interpole shoe

It was found that much useful data can be obtained easily under blocked-rotor conditions and that correlation of this information with normal short-circuit tests is quite good.

The experimental investigation which was conducted on a 90-horsepower d-c machine has led to the following observations.

1. The air-gap flux does not decrease as much as is expected during short circuit for two reasons:

(*a*) Steady-state proportionality between the leakage flux and shunt field current is not maintained during short circuit due to eddy currents in the yoke and saturation. The assumption of proportionality would be in error by approximately 25 per cent if it were used for the subject machine.

(*b*) Because of the existence of considerable partial linkages the change in leakage linkages is not related directly to a change in leakage flux.

2. Whenever use is made of the constant flux linkage theorem up to peak armature current it may entail an error of as much as 5 per cent for the subject machine due to an actual loss of flux linkages.

3. The solid interpoles are ineffective in providing sufficient flux to counteract the reactance voltage generated in the coil being commutated (Figure 1). They do, in fact, allow flux to build up in that region in a direction such that voltages are generated further opposing commutation.

4. Results available thus far indicate that there is a large unaccounted for potential drop within the armature winding.

5. Further work is needed to develop an equivalent circuit reflecting core losses which will describe a d-c machine more adequately during a short circuit.

Digest of paper **53-85**, "Transient Performance of D-C Machinery—I," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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Axial Magnetic Forces on Induction-Motor Rotors

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IN AN APPLICATION where an induction motor is the driving unit, the electromagnetic force on the induction-motor rotor is a component of axial shaft thrust. The various factors which determine this force are discussed qualitatively and, with one exception, are evaluated in this article.

The total axial force on an induction-motor rotor can be regarded as the sum of three force components:

1. The force due to the rate of change of air-gap permeance with axial displacement of the rotor.
2. The force due to skew in rotor or stator slots.
3. The force due to current in the rotor winding end connections.

The force due to the rate of change of air-gap permeance with rotor displacement is always in a direction to return the rotor to an equilibrium position or positions. In a particular motor operating at steady state, this force varies as the energy stored in the air gap and with rotor displacement. It is proportional to the square of the applied voltage and relatively independent of load. The stack ends and the ducts are the machine elements which determine the permeance variation. If fringing is neglected, the air-gap permeance of a machine with no ducts varies linearly with axial displacement of the rotor. Similarly, the permeance change due to each pair of opposing rotor and stator ducts is either zero or is linear with axial displacement of the rotor. The effect of fringing is to modify these variations as shown in Figure 1.

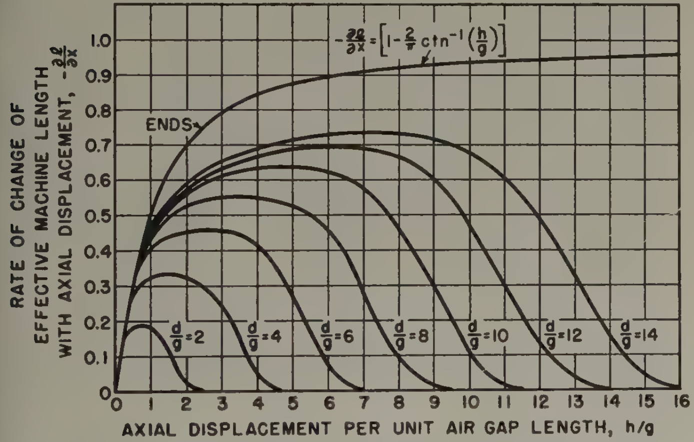

Figure 1. Rate of change of effective machine lengths with axial displacement of rotor (d = duct width)

Unless slots are skewed, this is the major force component during normal operation. Figure 2 illustrates the correlation of calculated and test values of this force component for a motor with one duct. The major factor causing the axial force produced to depart from the calculated value is the variation from designed values of rotor and stator lengths, duct widths, and duct locations. In machines designed with equal rotor and stator lengths and equal and directly opposite rotor and stator ducts, these variations always have the effect of producing a force lower than the properly calculated force. This is demonstrated by the curve of Figure 2.

Skew in rotor or stator slots has the effect of producing a unidirectional axial force independent of rotor position. In a particular machine this force is a linear function of the power transferred to the rotor. A literal expression for this force is developed in terms of torque and machine geometry.

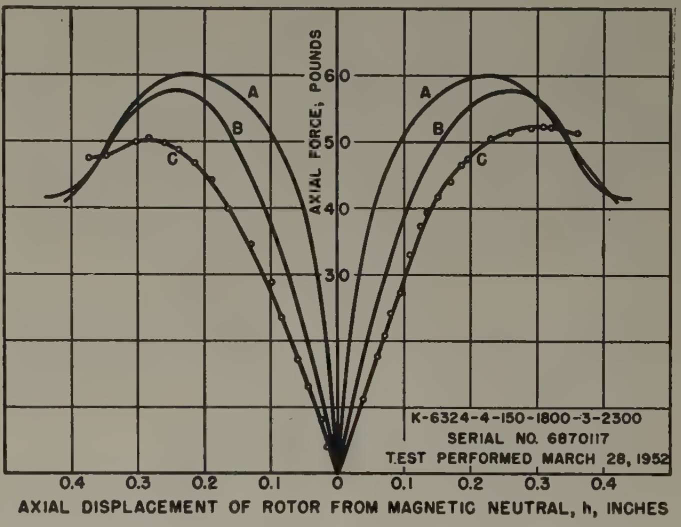

Figure 2. Correlation of calculated and test axial force characteristic for induction motor with one duct

The reaction between the current in the rotor winding end connections and the flux passing through these connections results in force in a direction to expel the rotor from the stator. The magnitude of this force in a particular machine varies with load, voltage, and rotor frequency. It depends upon the geometry of the winding end connections and hence varies between different designs. It is a maximum in squirrel-cage rotors with end rings immediately adjacent to the rotor ends. This force is not generally significant during steady stator operation but may become the dominant force during starting or other transient conditions. Experimental work is needed for quantitative study of this force component.

Digest of paper 53-124, "Axial Magnetic Forces on Induction-Motor Rotors," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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Capacitively Coupled Field Mapper

E. O. GILBERT   E. G. GILBERT

An electric analogue mapper is described whose accuracy, although limited by resistive paper and dielectric nonuniformity, is excellent. The maximum error in line position should not exceed 1 per cent of the maximum map dimension while the average error should be considerably less.

POISSONIAN or distributed-source fields occur often in present-day problems dealing with such subjects as torsional stress analysis, heat transfer, viscous fluid flow, eddy currents, and electric and magnetic fields. Since the mathematical solution of Poissonian fields has been possible only in several special cases, physical analogues have been developed for 2-dimensional fields. A highly successful physical analogue is the sandbed fluid mapper.[1–3] The electric analogue mapper described here, which was originated and developed by the authors, can give directly usable 2-dimensional solutions of high accuracy.

THE ANALOGUE FIELD MAP

THE MAPPER UTILIZES a resistive plotting surface and a coupling capacitor. The coupling capacitor is formed by the resistive surface and a parallel coupling electrode. A displacement current acting through this coupling capacitor sends a distributed current into the resistive surface. As shown in the appendix, this distributed current flow represents Poisson's equation. Boundary conditions are introduced by suitable conducting terminations of the resistive surface. The coupling electrode shape and area correspond to those of the distributed source. The displacement current density is readily controlled by the spacing of the coupling electrode and the resistive surface. Emphasis is placed on mappers of constant displacement current density.

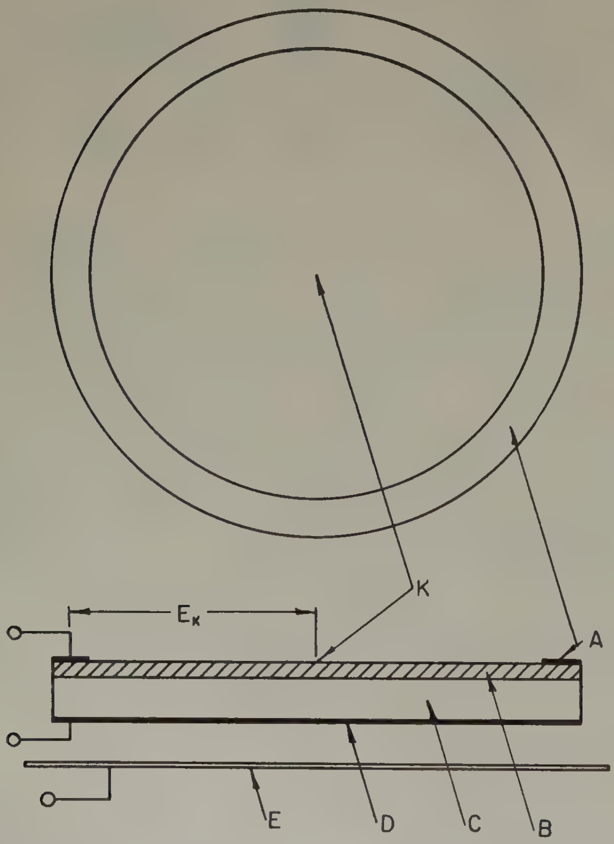

Figure 1. A circular map with guard electrode: A—conducting boundary; B—resistive paper; C—dielectric; D—conducting sheet; E—guard electrode; E$_K$—kernel voltage; K—kernel

In practice, Teledeltos* recording paper is used as a resistive surface. A dielectric material separates it from the coupling electrode, a conducting sheet of aluminum foil or silver paint. Silver paint is used for the conducting boundary of the Teledeltos paper. A circular map made of these materials is illustrated in Figure 1. A uniformly distributed source region is represented since the dielectric is uniform in thickness. This map could represent, for example, the magnetic field within a circular conductor of infinite length. In operation the terminals of the mapper, that is the conducting boundary line of the resistive paper and the conducting sheet, are connected to a source of alternating current. The resistance of the paper is small in comparison with the reactance of the coupling capacitor. For this reason the voltage drop across the resistive paper is a small percentage of the applied voltage and therefore a substantially uniform source of current density appears in the resistive paper over the conducting sheet. This uniform current flow represents the problem of the uniformly distributed source field. A null-type measuring circuit is used in conjunction with a probe to plot the equipotential lines on the resistive paper. These lines correspond to one set of the orthogonal system that is the solution of the desired field.

For the capacitively coupled field mapper to be a work-

Full text of paper **53-193**, "A Capacitively Coupled Field Mapper for 2-Dimensional Distributed-Source Field Problems," recommended by the AIEE Committee on Basic Sciences and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Southern District Meeting, Louisville, Ky., April 22–24, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

E. O. Gilbert and **E. G. Gilbert** are both at the University of Michigan, Ann Arbor, Mich.

The authors wish to acknowledge their special indebtedness to Professor A. D. Moore for his help and encouragement. Thanks are also expressed to Professor M. B. Stout and the many others at the University of Michigan who helped make this article possible.

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* Teledeltos paper is manufactured by the Western Union Telegraph Company.

able analogue, the current density appearing in the resistive paper must be inversely proportional to dielectric thickness; this requires that the voltage across the dielectric be the same at every point. However, the mapper works on the principle of a measurable voltage drop across the map surface. The error caused by this imperfect analogy was mathematically investigated for the circular map and found to be entirely negligible for any practical mapper.

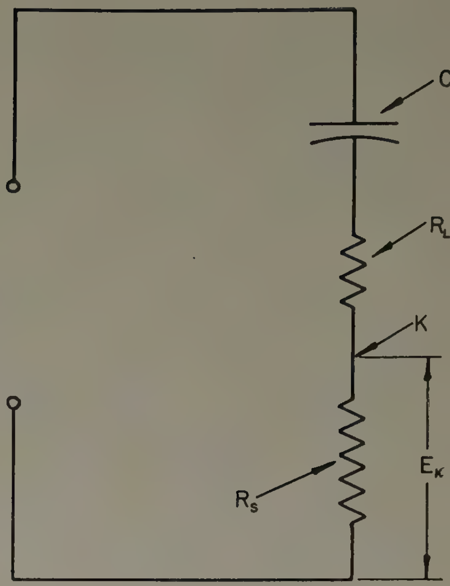


Figure 2. Equivalent map circuit: C—coupling capacitance; R_L—loss resistance; R_S—surface resistance; E_K—maximum surface voltage; K—kernel

THE EQUIVALENT CIRCUIT

A simplified circuit representation of the mapper would be useful in further work. An equivalent circuit is shown in Figure 2. It has proved to be highly accurate for all maps thus far measured. The impedance of the coupling capacitor C is generally 100 to 500 times as large as R_S which represents map surface resistance. The resistance R_L is apparent in measurement and is believed to denote loss in the coupling capacitor. Typical values of R_S range from 400 to 4,000 ohms. The point of maximum voltage on the resistive surface is the kernel. It is point K on the diagrams. The maximum surface voltage, E_K, will be referred to as the kernel voltage.

MEASUREMENT METHODS

The measurement of equipotential lines presents difficult problems which may be understood best by examining conditions under which a typical mapper might operate. The resistive paper is held near ground potential while the coupling electrode is excited to a potential of about 100 volts. With average conditions, less than 1 volt will appear across the map surface. In weak field regions the voltage gradient is extremely low and precise measurements must be made if points are to be located accurately. Minor changes in C or R_S can produce large changes in the measured position of equipotential lines. For this reason the stability of mapper components is extremely important. Capacitive drift (change in coupling capacity with time) and resistive drift (change in paper resistance with time) do exist and increase the difficulty of accurate measurement. These effects will be discussed more fully later.

All of the measuring circuits tried were of the null type. A vacuum-tube voltmeter would be ineffective because of the low voltages present and accuracy required. A null-type detector has proved convenient because it can give an audible signal not demanding that the operator be continually shifting his vision from the plotting surface to a visual indicator. The low voltage levels present indicate that steps should be taken to minimize stray couplings. This is shown to be true in actual practice, as without proper techniques deep nulls are impossible. The circuit diagrams will show where shielding is employed. A guard electrode placed near the high-potential coupling electrode is invaluable in reducing stray flux. Such a guard electrode is shown in Figure 1. A sensitive null indicator is required in all cases. Headphones in conjunction with a battery-operated bridge-amplifier make a good combination. A selective filter in the detector amplifier circuit is helpful in reducing the effects of hum pickup from nearby a-c lines. A sharp needle is the best probing tool since a dull point makes positive surface contact difficult. The afore-mentioned points are applicable to all of the circuits used. Map requirements have led to the development of three basic types of measuring circuits.

The first circuit is shown in Figure 3. The variable circuit elements R' and C are adjusted so point A has the same potential as the kernel. Any fraction of the kernel voltage then may be measured by setting the slider of R at the desired percentage of full kernel voltage. A Wagner ground circuit is used to eliminate the effects of stray detector capacity to ground. This circuit produces good nulls and satisfactory accuracy but requires bothersome adjustment of the Wagner ground circuit for each different potential measured. Capacitive and resistive drift also cause troublesome shifting in the measured position of equipotential lines. For these reasons the next measuring method is preferred.

The transformer circuit, shown in Figure 4, gives excellent results. Not only does it use less equipment than the previous circuit, but it is able to counteract the effects of

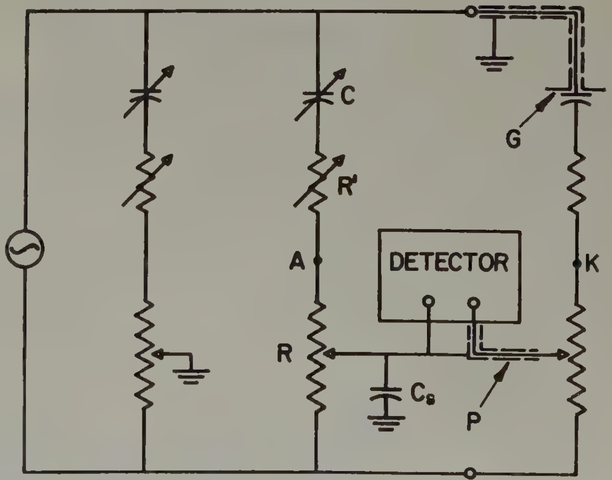


Figure 3. Measuring circuit with Wagner ground: C_S—stray detector capacitance to ground; G—guard electrode; P—shielded probe

capacitive drift in the map. The transformer gives a 180-degree phase shift so that point *A* may be adjusted to the same potential as the kernel. Capacitor *C* serves to correct phase shift in the transformer and its associated circuit. Since the equivalent capacitor of the map has by far the highest impedance of the series circuit, it is the main factor in controlling the total current through the map and the transformer primary. Thus, the voltage across *R* may be conveniently adjusted by changing *R′*. If the reactance of the map capacitor should increase slightly due to drift, then the current through the circuit would decrease slightly. This in turn would cause a slight drop in the kernel voltage and in the voltage across *R*. Since the potential of the kernel and point *A* rise and fall together, capacitive drift has no effect on circuit balance. This method does not compensate for the effects of resistive drift which may be minimized by proper handling of the resistive paper. The circuit is easy to adjust as there is only one control to change in measuring different potential lines. The stray capacity, C_S, can cause trouble if *R* is too large. Operation has been satisfactory when *R* was kept below about 500 ohms. This can be done easily by governing the turns ratio of the transformer. In all maps measured a turns ratio of n_1/n_2 equal to four has been satisfactory. A bridge-type transformer provides excellent isolation. It should be noted that the guard electrode is not returned to ground but is shunted across the oscillator. This has been found necessary to make certain that the transformer carries current governed only by the map capacitor; otherwise, the circuit would not completely counteract capacitive drift.

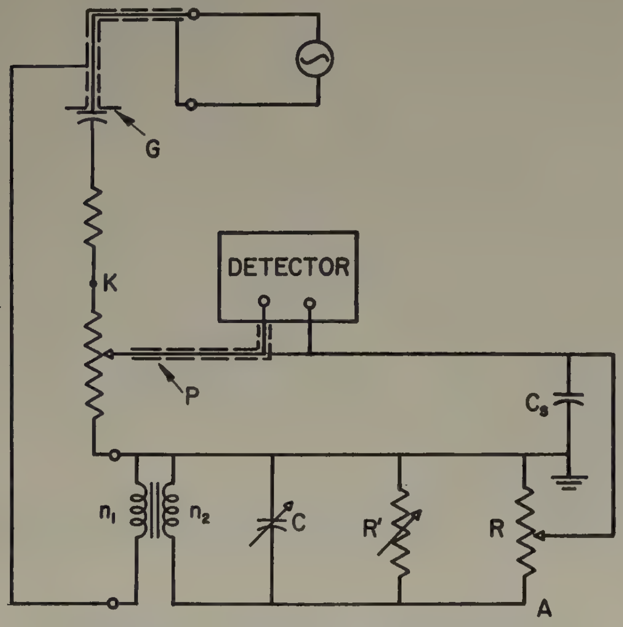


Figure 4. Transformer measuring circuit

A vacuum-tube circuit is shown in Figure 5. The measuring resistance *R* takes the form of a load in a cathode-follower amplifier. The step-up transformer is necessary since the voltage gain of the stage is less than unity, and since the cathode-follower input voltage is less than the kernel voltage. The grid terminal of the tube is kept in contact with the map somewhere near the kernel. Map loading is negligible because the input impedance of the tube is exceedingly high. Since the voltage across the measuring resistance varies as the voltage across the map, the circuit responds to neither capacitive nor resistive drift. This circuit is effective in operation only if the tube potentials are carefully stabilized. The measuring method has all the advantages of the transformer circuit, but does require more equipment.

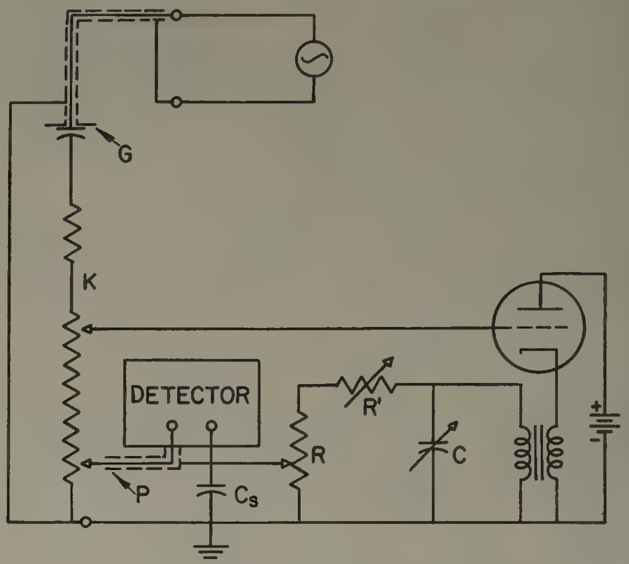


Figure 5. Vacuum-tube measuring circuit

The transformer circuit has been found very satisfactory and has been used in the majority of measurements. With proper control of resistive drift it is accurate, simple, and easy to use. A typical setup is shown in Figure 6. There are, no doubt, many other methods which will give excellent results. The examples presented here show what can be done with suitable circuitry. The final choice of method will depend upon the user's requirements.

CAUSES OF ERROR

ERRORS IN LINE POSITION are due to five causes: inaccuracy of measuring equipment, voltage drop across the map surface, nonuniformity of the dielectric, nonuniformity of the resistive paper, and boundary fringe flux. As mentioned before, errors due to surface voltage drop are extremely small in a practical mapper. This type of error is roughly proportional to distributed source area, the resistance per square of the paper, and the admittance per unit area of the capacitor. For a circular map of moderate area (100 square inches), thin paper dielectric (several mils), and usual frequency of operation (1,000 cycles), the maximum error in line position from this source is less than 0.01 per cent of the map diameter. Since the upward current density is dependent upon the dielectric thickness and the dielectric constant, these factors must be carefully controlled if accuracy is to be achieved. A homogeneous dielectric of high dimensional accuracy is necessary. Care must be taken also to insure the uniformity of the adhesive layers which are used to assemble the map. Another source of error is resistive paper nonuniformity. The nonuniformities of Teledeltos paper will be discussed in some detail later. At the edge of the conducting sheet the flux to the conducting paper will not change abruptly because of fringe flux effects. This fringing can cause a slight error at the distributed source boundary. It is believed that this error is extremely small in a practical map where the dielectric thickness is small compared to map area. When boundaries of the resistive paper and the coupling electrode coincide, the fringe flux may be eliminated by extending the coupling electrode. This has been done in Figure 1.

THE CONDUCTING PAPER

TELEDELTOS PAPER has proved to be a good resistive surface medium. It is readily prepared and maps of great complexity can be built quickly at negligible cost. Conducting boundaries are simply applied using silver paint. The paper is available in two types, high and low resistance. The low-resistance paper, type *L-39*, has a resistance of approximately 2,000 ohms per square and is used because it gives less surface voltage drop.

Teledeltos paper is not perfectly uniform in its resistive properties. The major variation in resistance seems to depend on direction of current flow. A maximum difference in resistance occurs when current flow is first parallel and then perpendicular to the direction in which the paper was rolled. Variations as high as 16 per cent and as low as 2 per cent have been measured in different samples. If selection of the paper were possible this error could be eliminated or greatly minimized. The error in line position caused by this variation depends upon map geometry. In most cases the error is very small. Other relatively minor nonuniformities are believed to exist. It is hoped that a resistive paper of high uniformity will be made available for mapping purposes. Such a paper would have great value for mapping either Laplacian or Poissonian fields.

An important factor in the use of Teledeltos paper is its sensitivity to moisture. Changes in humidity have produced resistance variations in excess of 1 per cent. Such variations are the main cause of resistive drift. The drift can be minimized by proper map construction. The face side of Teledeltos has a dull finish and is quite porous while the reverse side is shiny and nonporous. If the face side is removed from air contact by cementing it to the dielectric, the drift will be quite small. Hand moisture can cause noticeable drift and it is advisable not to touch the map while plotting. If it is desired to eliminate drift completely, it can be done by coating the paper with a thin layer of acrylic plastic from a spray-type bomb. This practice is not recommended unless necessary since it makes probing quite difficult. In most cases the first precaution is entirely adequate.

DIELECTRIC MATERIAL

THERE IS A PROBLEM in finding dielectric materials that are homogeneous and dimensionally accurate. The problem is further complicated if an effort is made to eliminate capacitive drift. The form of mapper construction makes it extremely difficult to construct a stable coupling capacitor. It is better to eliminate the effects of capacitive drift by suitable measuring circuitry than to eliminate the capacitive drift itself. If high accuracy is not needed, common dielectrics such as paper and plastics may be used. A good grade of window glass is an excellent material since it is dimensionally accurate (within a few per cent), resistant to attack of adhesives, and easy to obtain. The final choice of a dielectric will depend on how severe the user's accuracy requirements are.

MAP CONSTRUCTION

TO ILLUSTRATE possible map-making techniques, the construction of a uniformly distributed source mapper will be described. The dielectric, in this case a sheet of glass, is sprayed with acrylic plastic until it is just wet. The Teledeltos paper is then applied and rolled smooth. Considerable pressure on the roller is necessary to remove excess plastic and to insure a uniform plastic film. The uniformity of the film may be checked easily by viewing the paper through the glass. Since the plastic sets fairly rapidly some speed is required in executing these steps. This method of assembly is fast and produces results far superior to those using the more common cements, glues, or pastes. The coupling electrode may be either of silver

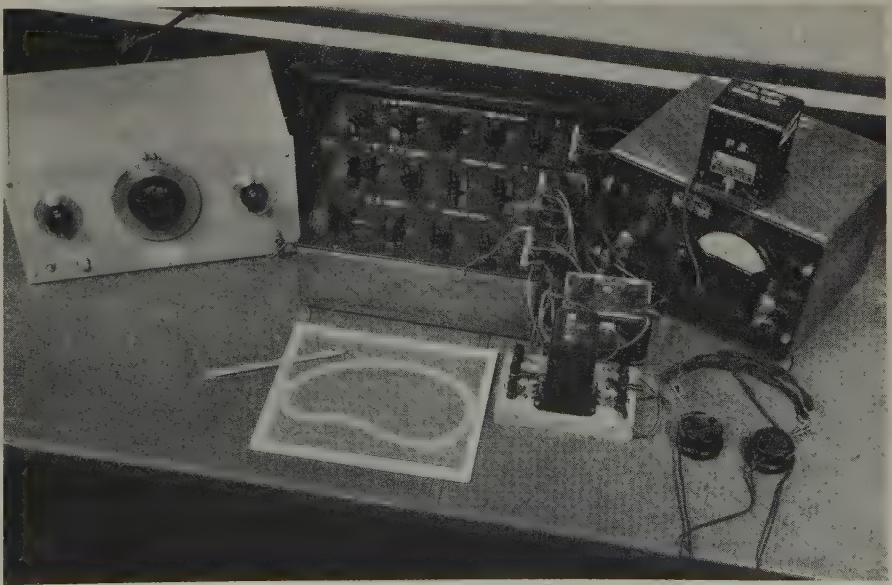


Figure 6. A typical experimental setup using the transformer measuring circuit

paint or aluminum foil. The foil is quickly applied using the same technique as is used with the Teledeltos paper. If small bubbles appear they can be removed easily by piercing them with a pin and then rolling them flat. Correct foil uniformity will result in a mirrorlike surface. The foil then should be trimmed so that it covers only the area where distributed flow takes place. The silver paint is useful in patching torn foil. Silver paint may replace the foil but its application is more time consuming and costly. The map is then ready for its associated wires, conducting boundaries, and guard electrode.

Conducting boundaries are easily affixed to the Teledeltos paper with silver paint. The silver paint is a commercially available product used in printed circuit work. Where high accuracy is desired the paint may be applied with a ruling pen. A boundary width of 3/8 inch has been found adequate. Tape is used to hold the wires in contact with the map boundaries. Electrical connection is then made by daubing the wires to the boundaries with silver paint. To assure high conductivity such connections are made every few inches. The wires may be held more securely if they are kinked or looped. Connections to the coupling electrode are made in the same manner. To protect the map and its connecting wires it is helpful to mount it on stiff cardboard. A foil guard electrode is cut slightly larger than the coupling electrode and is affixed to the top of the mounting cardboard with cement. A lead is then attached to the guard electrode and a hole punched through the cardboard and guard electrode for the capacitor lead. A sheet of paper is used to separate the guard electrode and the bottom of the coupling electrode; the components are then assembled and taped together. When the shield wire is attached and secured to the mounting cardboard, the mapper is ready for operation.

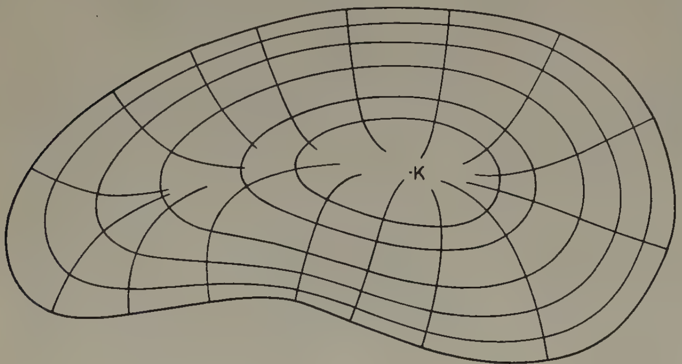


Figure 7. The solution of a uniformly distributed source field by two methods. The closed curves are equipotentials obtained from the capacitively coupled mapper. The set of flow lines was obtained from a sandbed fluid mapper. The excellent orthogonality of the sets shows close agreement between the two solutions

RESULTS

The accuracy of the capacitively coupled mapper is good. A circular map as in Figure 1 was constructed with a glass-plate dielectric with a diameter of 20.0 centimeters. The maximum error in equipotential line position was less than 0.1 centimeter. Average error was much less. Complex fields have been checked with sandbed fluid mappers. Such a check is shown in Figure 7. The fluid map is by Professor A. D. Moore of the University of Michigan. Excellent orthogonality of equipotential lines and representative fluid-flow lines indicate close agreement. The fluid-flow lines also seem to originate from the kernel which was found by the capacitively coupled mapper.

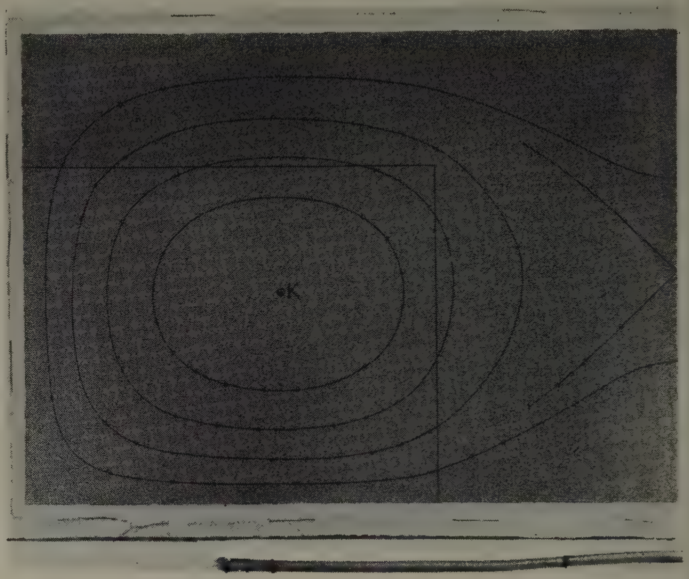


Figure 8. Actual mapper representing the magnetic flux within a rectangular duct of infinite permeability and length. The duct holds two rectangular, symmetrically placed conductors with equal, uniform current densities in the same direction. The left half of the duct is shown with the centerline at the right. One of the conductors can be seen in the lower left corner. The flux lines and the kernel K are shown

Figure 8 shows an actual mapper as used to solve a magnetic field problem. Note how the symmetry of the problem enables the mapper to be simplified. The current enters the resistive paper in the distributed source area at the lower left. It leaves from the conducting boundaries at the top, left, and bottom. Here, the equipotentials represent magnetic flux lines. No refraction of flux lines occurs at the distributed source boundary. This is as it should be when the permeabilities are the same on either side of the boundary.

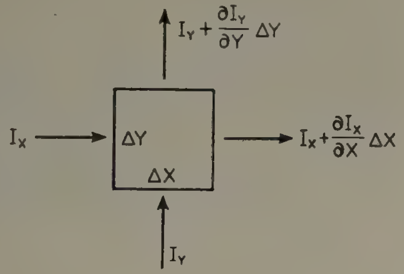
CONCLUSION

At present the accuracy of the mapper is limited by resistive paper and dielectric nonuniformity. Even so, results obtainable are excellent. The maximum error in line position should not exceed 1 per cent of the maximum map dimension and the average error should be much less. The time involved in making and using a mapper such as the one described is in the order of 3 to 4 hours. The value of any potential line can be determined easily. In most cases the equipotential lines are the ones desired in the final solution.

The mapper should be easily applicable to regions of nonuniform displacement current density. Though such a mapper has not yet been constructed, little trouble is anticipated. The method of capacitive coupling might be applied also to the electrolytic tank, by-passing the problem of nonuniform resistive paper. The electrolytic tank might make possible also the solution of 3-dimensional fields with axial symmetry.

Appendix

If the capacitively coupled field mapper is to solve 2-dimensional fields of the distributed-source type it must satisfy Poisson's equation. In the following development the voltage drop across the resistive paper is considered very small in comparison with the applied voltage. Therefore the displacement current density appearing in the resistive paper is inversely proportional to the dielectric thickness. Let J equal the displacement current density at any point in the distributed source area. Let K equal the resistance per square of the resistive paper. Consider the sum of the currents leaving a small area in the xy plane as illustrated in Figure 9.



$I_Y + \frac{\partial I_Y}{\partial Y}\Delta Y$
I_X
ΔY
ΔX
$I_X + \frac{\partial I_X}{\partial X}\Delta X$
I_Y

Figure 9. An area in the xy plane used in the development of Poisson's equation

$$\frac{\partial I_x}{\partial x}\Delta x+\frac{\partial I_y}{\partial y}\Delta y+J\Delta x\Delta y=0 \qquad (1)$$

The voltage drops across the area are

$$\Delta V_x=\frac{\partial V}{\partial x}\Delta x=I_xK\frac{\Delta x}{\Delta y}$$

$$I_x=\frac{1}{K}\Delta y\frac{\partial V}{\partial x}$$

$$\frac{\partial I_x}{\partial x}=\frac{1}{K}\Delta y\frac{\partial^2 V}{\partial x^2} \qquad (2)$$

$$\Delta V_y=\frac{\partial V}{\partial y}\Delta y=I_yK\frac{\Delta y}{\Delta x}$$

$$I_y=\frac{1}{K}\Delta x\frac{\partial V}{\partial y}$$

$$\frac{\partial I_y}{\partial y}=\frac{1}{K}\Delta x\frac{\partial^2 V}{\partial y^2} \qquad (3)$$

Substitute equations 2 and 3 in equation 1 and the result is

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}=-KJ \qquad (4)$$

Equation 4 is Poisson's equation for two dimensions.

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2. Soap Film and Sandbed Mapper Techniques, **A. D. Moore.** *Journal of Applied Mechanics* (New York, N. Y.), volume 17, September 1950, pages 291–8.

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New Device Makes X-Ray Images 1,000 Times Brighter

A new X-ray image amplifier that produces images 800 to 1,200 times brighter than those obtained with the conventional fluoroscope has been announced by the North American Philips Company, Inc. The device is a development of the Philips Laboratories, Eindhoven, Holland.

When X-raying the human body, intensities must be held down so that tissues are not damaged. This forces the radiologist to work with very weak images on the fluoroscope screen. The X-ray image amplifier intensifies these weak images approvimately 1,000 times.

The new device consists of an evacuated glass tube presently about 18 inches long and 7 inches in diameter with one flat end and the other hemispherical, curving outward. Inside the hemispherical end is a curved fluoroscopic screen in direct contact with a photocathode. On the inside at the flat end is a second fluorescent screen, reduced 9 times inside. External to the glass tube but mechanically coupled to it is a simple optical microscope with a magnification of approximately 9.

In use the X-ray image amplifier is used in place of the conventional fluoroscope screen and X rays pass through the hemispherical end of the glass tube to the internal screen which fluoresces. The fluorescent light sets electrons free from the photocathode and the number of photoelectrons released per second is proportional to the intensity of the fluoroscopic screen at that point. The luminous image with all its variations in brightness is thus transformed into an electronic image with corresponding variations in current density. By means of an electric field of a certain configuration (electrostatic electronic lens) this electronic image is reproduced on the viewing screen, reduced 9 times in size. The energy of the electrons falling on this screen is in part converted to fluorescent light, and a reproduction of the image is seen on the viewing screen reduced 9 times. This reduced image is viewed through a simple microscope of about 9 magnification, and finally the image is seen erect and in its original size, since both the electronic lens and the microscope produce inverted images.

The image seen through the microscope is identical with that seen on ordinary fluoroscope screen but it is 1,000 times brighter. The X-ray image amplifier makes it unnecessary for the radiologist to condition his eyes in a dark room for 15 minutes prior to examinations. In fact, this work can be performed in a room having nearly normal illumination. The amplifier can be used with film cameras to solve the problem of x-ray cinematography.

Application of Ground-Fault Neutralizers

AIEE COMMITTEE REPORT

GROUND-FAULT NEUTRALIZERS have been applied principally in the range of medium transmission voltages. The effectiveness of ground-fault neutralizers on a system depends on the ratio of single line-to-ground faults in the total number of nonpersisting faults. This ratio is influenced by the transmission-line configuration, the line insulation employed, and the structure-footing resistance if structure downleads are used. Where this ratio has been high, ground-fault neutralizers have provided an excellent record in reducing line outages 80 to 90 per cent.

The intent of this application guide is to present the various criteria which may effect a proper application of ground-fault neutralizers to a system. Included are the factors which determine the ground-fault neutralizer ratings required. For example:

The nominal current rating of a neutralizer is specified as a range of currents. The theory of neutralizer operation demonstrates that, to accomplish neutralization of the fault current, the neutralizer current must be equal to the charging current in the line-to-ground fault. The charging current is essentially proportional to the length of transmission lines (overhead line and/or underground cables) in the system. This charging current can be calculated by various analytical methods. However, experience has shown that the methods available invariably give lower values than actual test determinations.

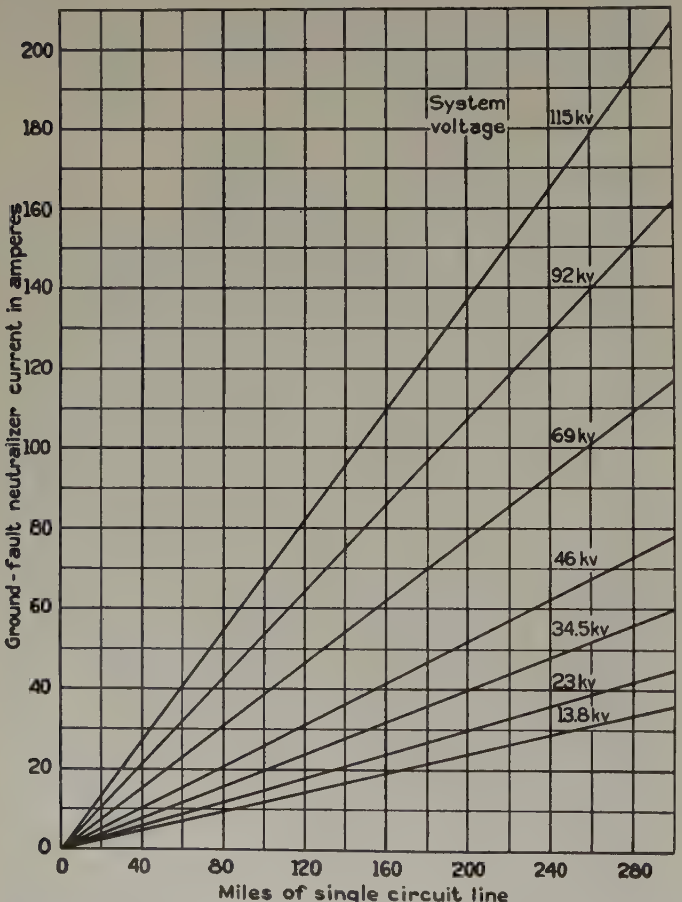

Figure 1. Curves, based on average data, indicating approximately the current rating a neutralizer should have for protection of single-circuit open-wire lines of various lengths and voltages

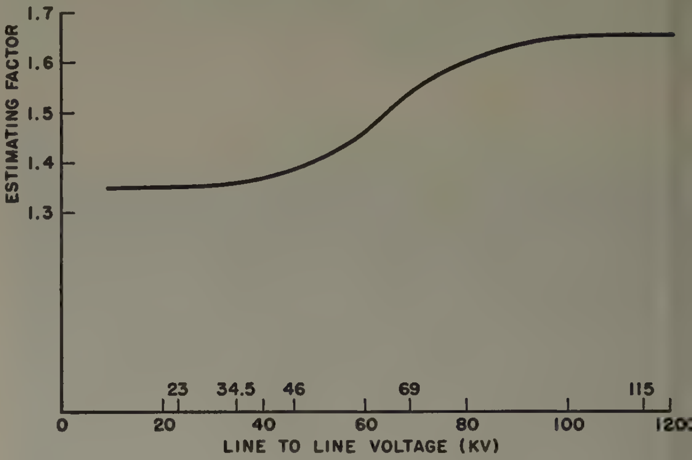

Figure 2. Estimating factors for converting miles of double-circuit line to equivalent miles of single-circuit line

The curves of Figure 1, based on average values, indicate the approximate current rating of a ground-fault neutralizer as a function of the number of miles of single-circuit overhead line in service for various nominal voltages.

For double-circuit lines on the same tower or poles, the particular line sections can be reduced to approximate equivalent single-circuit line miles of overhead line by increasing the single-circuit mileage by a factor indicated in Figure 2. For lines having overhead ground wires, the line section can be converted to approximate single-circuit miles of overhead lines by using multiplying factors, such as 1.08 for one ground wire and 1.15 for two ground wires. For cables, the particular sections can be converted to approximate equivalent sections of single-circuit overhead line by the following factors: 1 mile of 3-conductor cable equals 25 miles; 1 mile of 1-conductor cable, 50 miles.

Ground-fault neutralizers can be installed on any 3-phase transmission system, whether radial or network, provided certain application criteria are met.

Neutralizers have been installed on overhead line and underground cable systems in the United States with voltages from 2.4 to 230 kv. Their choice for application as protective devices depends on an analysis weighing the benefits of the schemes and the comparative economics.

Digest of paper 53-15, "Guide for Application of Ground-Fault Neutralizers," recommended by the AIEE Committee on Protective Devices and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

This paper is a report by the AIEE Working Group of Fault Limiting Devices Subcommittee of the Protective Devices Committee. Members of the group are J. E. Clem, Chairman; S. S. Cook, N. E. Dillow, E. B. Doescher, C. W. Gragg, W. D. Hardaway, R. E. Neidig, and M. Scharfl.

The New Adjustable Inverse CO Relay

W. K. SONNEMANN
MEMBER AIEE

This new relay provides 3-point control of the time curve and both powerful and simple adjustments to obtain any of various standard curves. It also achieves mechanical simplification by the elimination of gears and through other improvements.

THE GOALS SOUGHT in this new version of an old familiar relay were: (1) improved accuracy, (2) adjustability of the characteristic current–time curves, and (3) simplification and improvement of mechanical design. The first two items are inherently related, for to make a relay meet a prescribed current–time curve within close tolerances, separate adjustments must be provided to affect the curve at different points as a means to compensate for variations in materials and manufacture that are bound to occur. Just how these adjustments work will be described. The third point mentioned was accomplished by the elimination of gears, the use of a truly adjustable permanent magnet, the redesign of the tap block to furnish metal to metal contact, and numerous other detailed improvements.

THE BASIC ELEMENT

THE ELECTROMAGNET USED in the new relay is illustrated in Figure 1. It is a completely new electromagnet and is called the *E* element, taking its name after the shape of the lower portion. The laminated core is in four pieces. The center section, which looks like an inverted T, carries the main coil. The current I_1 in the main coil sets up a total flux ϕ_1, which crosses the disk air gap into the keeper. On its return circuit, the total flux ϕ_1 splits into two component parts, ϕ_2 and ϕ_3. The flux ϕ_2 returns through the disk air gap and through the left-hand L-shaped leg of the laminated core. It induces a voltage in the lag coil which causes the current I_2 to flow. The component of flux ϕ_3 returns through the disk air gap and through the right-hand L-shaped leg of the laminated core.

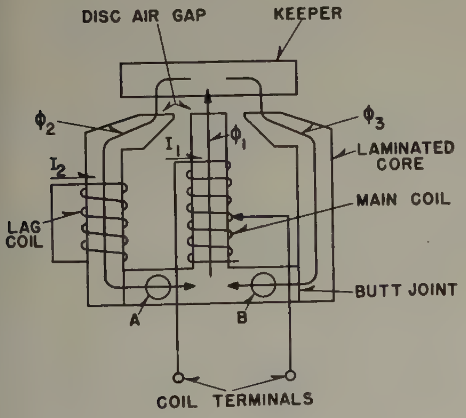

Figure 1. Diagram of the electromagnet showing current and flux circuits

To simplify the diagram, the holes which are necessary in the laminations for mounting purposes have been omitted. Two other holes are shown, however, labeled *A* and *B*. These are punched through the laminations for the purpose of introducing a saturable section in the magnetic circuits involved for the fluxes ϕ_2 and ϕ_3. If the holes are empty they have a maximum effect. When they are filled with adjustable steel plugs, it is obvious that their effect is reduced to a minimum. Steel plugs with threaded shanks giving vernier adjustment are provided to fill or partially fill these holes.

Inasmuch as the flux ϕ_2 passes through the lag coil, it is lagged in time-phase position behind the fluxes ϕ_1 and ϕ_3. This is used to obtain a split-phase-motor effect so that torque will be produced in the relay. A complete vector diagram analysis has been presented.[1]

No form of lag coil on the right-hand leg which is traversed by ϕ_3 is shown in Figure 1. If a lag coil were placed on this leg duplicating the one on the left-hand leg, it should be apparent that the effects of the two coils would neutralize each other and no torque whatever would be produced. Actually, the design involves a small 1-turn coil shunted by an adjustable resistor which is used for control purposes. In effect, the flux ϕ_2 is somewhat overlagged to produce too much torque, and the excess is neutralized by the 1-turn coil on the right-hand leg shunted by the adjustable resistor. This forms a control on the efficiency of the electromagnet such that several tolerances in manufacture and materials can be neutralized out with one adjustment at one point. The combination of the 1-turn coil and the small adjustable resistor is called the tap-value adjuster. It is utilized to make the actual tripping current agree with the tap-plate marking.

THE ADJUSTMENTS

IN GENERAL, there are three characteristics in a nongeared induction overcurrent relay where accuracy is desired. Without endeavoring to establish the relative importance of these characteristics, they are listed in the following order for convenience.

1. The relay should trip at tap value current within close tolerances.

Revised text of paper **53-74**, "A New Inverse Time Overcurrent Relay With Adjustable Characteristics," recommended by the AIEE Committee on Relays and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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2. It is desirable for the disk to move at a constant current value from any starting position as indicated by time dial settings.

3. The shape of the current–time curve should conform with the published or pattern curve within close tolerances.

The first two characteristics mentioned are interrelated to a certain extent and means have been provided in this new relay to control them separately within desirably close limits. The control of these two points together forms a first control for the shape of the current–time curve listed as characteristic number 3 in the foregoing. Just how these are accomplished will be detailed in a later paragraph, but their effect as a control on the current–time curve is illustrated by the asymptote control point number 1 on Figure 2. It is a characteristic of nongeared relays that the current–time curve approaches infinite time as a limit at tap value current. Thus, in Figure 2 an asymptote for the curve has been erected from tap value current on the current scale parallel with the time scale. This asymptote can be moved to the right or to the left as indicated by the tolerance limits (shown to an exaggerated scale) depending upon the accuracy with which the actual minimum trip current agrees with the tap plate marking and based on the current being plotted in multiples of tap value, which is the normal procedure. The location of this asymptote forms control point number 1 of the shape of the current–time curve.

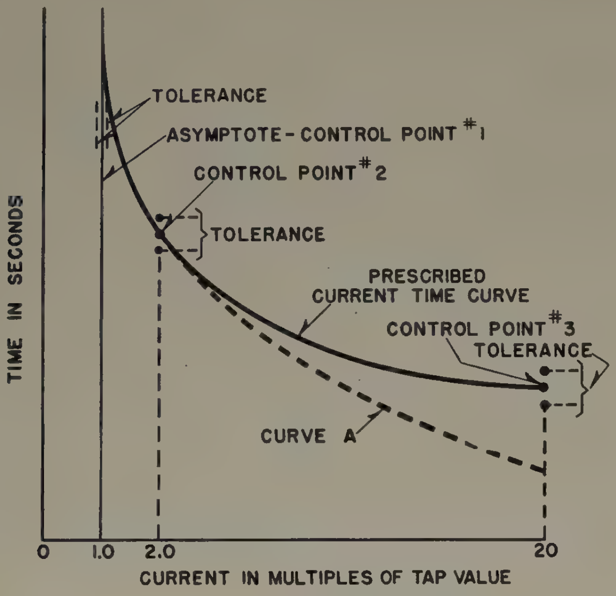

Figure 2. Typical current–time curve showing points of calibration

The current–time curves of induction relays may be raised or lowered as a whole by adjustment of the strength of the damping magnet. This is illustrated by control point number 2 in Figure 2. The time of operation from the number 11 time dial setting is adjusted within tolerances as indicated at two times tap value current. This adjustment is made at two times tap value current because, for the inverse and very inverse relay characteristics which this new relay provides, the electromagnet is unsaturated at this point. At the relatively long time involved, the effect of synchronous speed is very small, hence the effect of the damping magnet is by far the greatest in controlling the time value.

It is of interest to note that the damping magnet actually used is a completely new design involving Alnico V material and it is physically fixed in position. The adjustment is made by raising or lowering the keeper screw in vernier fashion, thus changing the length of the air gap, thereby controlling the amount of the air gap flux, and providing a wide range of adjustment. This wide range of adjustment not only provides close limits for control point number 2, but also makes it possible to adjust the relay to either the inverse or the very inverse characteristic where the time values are 27 and 18.3 seconds respectively.

As saturation sets in at the high current values, the shape of the curve is dependent upon the degree of saturation. For example, in Figure 2, the dotted-line curve *A* would be obtained with an electromagnet with less saturation than the one used here, which provides the solid-line curve labeled prescribed current–time curve. The two plugs used to fill the holes *A* and *B* of Figure 1 are used to adjust the degree of saturation. The adjustment is made at 20 times tap value current, which gives control point number 3, wherein the time of operation is held within tolerances as illustrated, again to an exaggerated scale. It is of interest to note that either of the two plugs may be withdrawn from the holes either part way or all the way as may be required. Withdrawing the left-hand plug makes the relay run slower and withdrawing the right-hand plug makes the relay run faster.

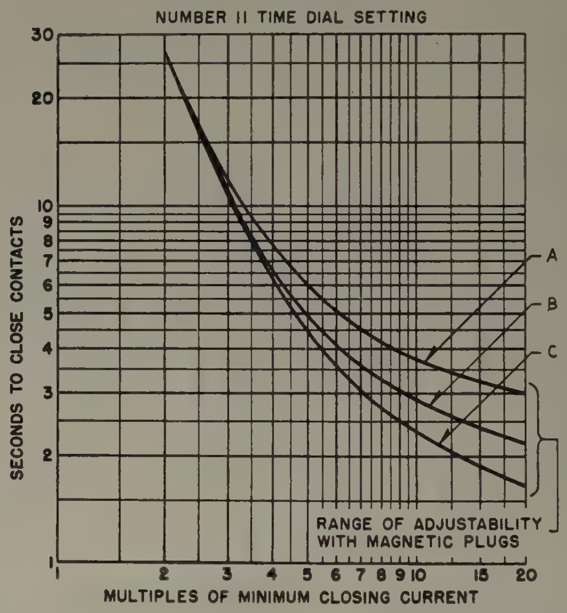

Figure 3. Example of the range of adjustability of the current–time characteristics

The three control points discussed not only make it possible to adjust the current–time characteristics of the relay to a prescribed pattern curve within close tolerances, but also make it possible to obtain other curve shapes, within limits, as may be required to fit particular applications. The range of possibilities is partially illustrated in Figure 3. This figure shows curves which are of different shape and it should be remembered that any one of them, or anything in between, may be moved up or down on the time scale by means of the damping magnet adjustment. Thus, an infinite number of time curves are available.

DUALIZED CONTROL OF MINIMUM TRIP

IT HAS BEEN MENTIONED that the adjustment of the relay to tap value current and the adjustment for constant current at various time dial positions are interrelated. This has led to a new philosophy in the adjustment of the spiral control spring, as described in the following.

In a nongeared relay design, it is possible to design the disk so that the electrical torque increases as the disk rotates in order to compensate for the increasing tension of the spiral control spring. This is accomplished in this relay by cutting the edge of the disk in a spiral. As the disk moves through the electromagnet, the radius constantly increases, placing more conducting material in the disk air gap, thereby uniformly increasing the electrical torque. This is a linear function of torque versus displacement. The increasing torque of the spiral control spring is also a linear function.

Typical torque curves are illustrated in Figure 4 where T_e represents electrical torque curves and T_S represents the spring torque curve. With a given electromagnet, the curves labeled I_1, I_2, and I_3 represent different displacement-torque curves resulting from different current values. These are all straight lines and radiate from point m. The point m is located at an angle of θ_e degrees to the left of the full contact open position indicated by 0 degrees contact travel or number 11 time dial position in this figure. This particular angle is a design constant fixed by the degree of spiral used and the location of the electromagnet with respect to the edge of the disk. It is not subject to adjustment.

The several typical curves I_1, I_2, and I_3 could represent equally well variations in electrical torque produced in different manufactured samples of the same electromagnet operating at one particular current value. Thus, these curves could be said to represent manufacturing tolerances.

The spring torque curves T_S are typically illustrated by K_1, K_2, and K_3, where the variations are accounted for by allowable tolerances in the spring constant. These curves are drawn radiating from the point p at the angle θ_S in Figure 4 for the specific purpose of separating them from the electrical torque curves. The angle θ_S is adjustable, however, by means of the slotted spring adjuster plate. By means of this adjustment, the angle θ_S may be made equal to the angle θ_e so that points p and m coincide. When this occurs, it follows that some particular and constant current value will yield an electrical torque curve which will exactly match the spring torque curve. In test, the angles are not measured, but the adjustment of spring windup, controlling θ_S, is simply made by adjusting the spring until the electrical torque balances the spring torque at all time dial positions between 0 and number 11 at whatever current value is required.

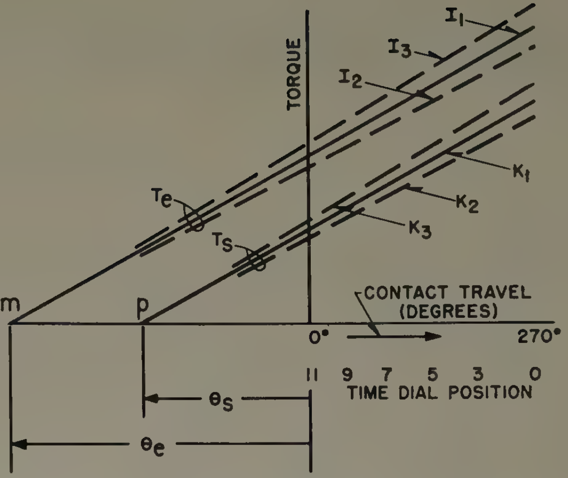

Figure 4. Illustrative torque curves for the electromagnet and the control spring

With a permanently fixed compensation, such as a disk with a spiral edge, there exists only one degree of windup of the spring which will match this compensation perfectly. The constant current value which is involved may or may not agree with tap value current within the established limits which are to be maintained. This constitutes the new philosophy on the adjustment of the spiral control spring. When this constant value has been determined, which is a very simple matter, it then is raised or lowered as may be required by means of the tap value adjuster previously described so that its numerical value will agree with the tap marking within established tolerances.

By contrast, in other relays, both geared and nongeared, the spring tension adjustment has always been used for the sole purpose of keeping the minimum trip current within desirably close limits based on the tap value marking. Thus, the spring tension adjustment was not primarily a control on curve shape. In the new relay, the spring tension adjustment is made without regard to minimum trip current, as described, thus freeing the tap value adjuster for controlling curve shape at the infinite time or minimum trip point.

CONCLUSIONS

UP TO THIS TIME in the relay art, there has been basically a 1-point control of the time curve. This was accomplished by means of the damping magnet adjustment only. The new relay provides a 3-point control of the time curve with obvious advantages from an accuracy standpoint. The new relay also provides powerful and simple adjustments such that either of two standard curve shapes, the inverse or the very inverse, as well as other than standard curves can be obtained with one relay. Mechanical simplification has been obtained through the elimination of gears and through other improvements.

REFERENCE

1. Principles of Induction-Type Relay Design, **W. E. Glassburn, W. K. Sonnemann.** AIEE *Transactions*, volume 72, 1953 (Paper 53-75).

A Mechanism for the Fuse Pre-arcing Period

E. B. CARNE
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WHEN FAULT CURRENT FLOWS in a fuse element, the temperature distribution along the fuse wire, at the instant of melting, depends upon the fault magnitude and on the dimensions of the fuse cartridge. If the current is low, and near to minimum fusing current, and the cartridge dimensions are normal, or, if the current is high and the cartridge is very short, the distribution will assume a parabolic form, and melting will occur at the center of the wire. If the current is high and the cartridge dimensions are normal, or, if the current is low and the cartridge is very long, the distribution will have a rectangular form, and most of the wire will melt at the same time. The melting depends on current density and wire parameter.

When current flows in a conductor, a pinch pressure is produced which causes the melting temperature at the center of the wire to rise above the melting temperature of the surface. The form of this Melting Temperature Distribution is shown in Figure 1, where Θ_o, θ_o are the melting temperatures at the center and surface of the wire. The Conduction Temperature Distribution is also shown. The orientation of these curves depends upon the current density Π. If Π is greater than some critical value A, the curves are as shown in Figure 1*A*, and the wire begins to melt from the surface, inwards. If $\Pi < A$, the orientation is reversed, as shown in Figure 1*B*, and melting occurs first at the center of the wire. In this case, breakup depends on the build-up of an internal pressure sufficient to rupture the wire at some weakness. When melting occurs from the surface, inwards, the surface forces are exactly those of a simple molten cylinder, and breakup depends on the parameters of the molten skin.

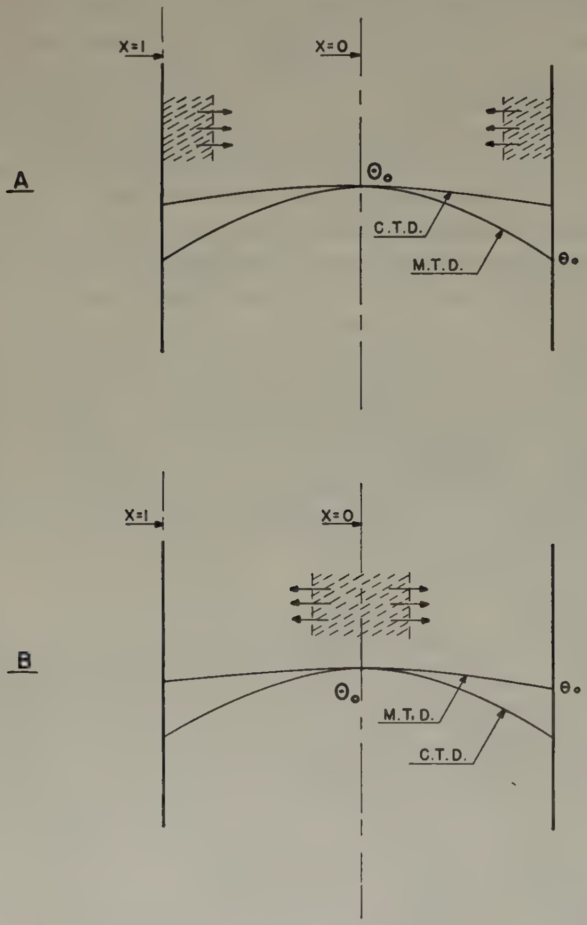

Figure 1. The effect of the relative orientation of the Melting Temperature Distribution and the Conduction Temperature Distribution on the melting of a fuse wire

A—Melting occurs from the surface, inwards
B—Melting occurs from the inside, outwards

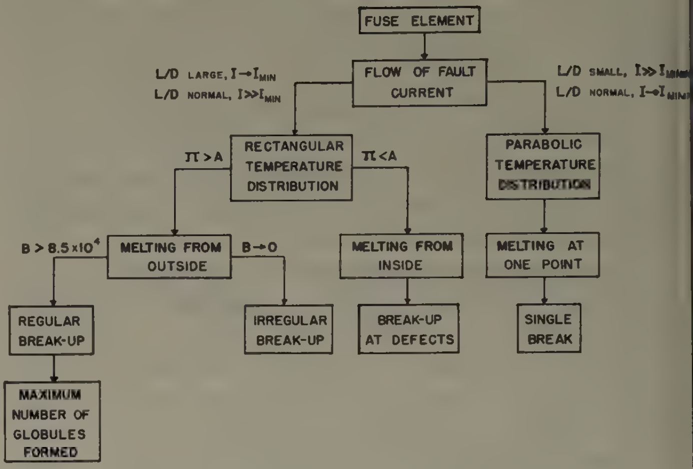
FUSE ELEMENT
L/D LARGE, $I \to I_{MIN}$
L/D NORMAL, $I \gg I_{MIN}$
FLOW OF FAULT CURRENT
L/D SMALL, $I \gg I_{MIN}$
L/D NORMAL, $I \to I_{MIN}$
$\Pi > A$
RECTANGULAR TEMPERATURE DISTRIBUTION
$\Pi < A$
PARABOLIC TEMPERATURE DISTRIBUTION
$B > 8.5 \times 10^4$
MELTING FROM OUTSIDE
$B \to 0$
MELTING FROM INSIDE
MELTING AT ONE POINT
REGULAR BREAK-UP
IRREGULAR BREAK-UP
BREAK-UP AT DEFECTS
SINGLE BREAK
MAXIMUM NUMBER OF GLOBULES FORMED

Figure 2. A graphic summary of the mechanism of the prearcing period

If the quantity $Tr_o/m_o\nu^2$, where T=surface tension of the molten metal, r_o=undisturbed radius of wire, m_o= density of the molten metal, and ν=kinematic viscosity of molten metal, be denoted by B, the type of breakup is determined by the magnitude of this quantity. If $B > 8.5 \times 10^4$ centimeter-gram-second-units, and provided the original surface of the wire closely approximates a cylinder, the wire will break up in a regular fashion to produce $1/9r_o$ globules per unit length. If $B \to 0$, the breakup will be irregular, and the breaks will be far apart. The complete mechanism is summarized in Figure 2.

Digest of paper **53-186**, "A Mechanism for the Fuse Pre-arcing Period," recommended by the AIEE Committee on Switchgear and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Southern District Meeting, Louisville, Ky., April 22–24, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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This paper is a summary of part of a thesis presented to the University of London, England, in partial fulfillment of the requirements for the degree of doctor of philosophy. The work described was performed in the Electrical Engineering Department of Queen Mary College. The author would like to acknowledge the advice and encouragement of Professor W. J. John and of Dr. H. Tropper, W. B. Diamand, and A. E. Guile. Thanks are also due to the Governors of Queen Mary College and to the Senate of the University of London for financial support.

Capacitors in Power Systems With Rectifier Loads

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THE PRINCIPAL SOURCES of system harmonics have been rotating machines and transformers. More recently, the widespread application of apparatus taking nonsinusoidal current, particularly mercury-arc rectifiers, has introduced other sources of system harmonics. These harmonics often require consideration when rectifiers and capacitors are connected to the same system.

The circuit action of apparatus which takes nonsinusoidal current from a system may be approximated by an equivalent circuit, so far as harmonics are concerned. In the equivalent circuit, the apparatus taking nonsinusoidal current is replaced by a harmonic generator which delivers to the supply circuit the same harmonic currents taken by the apparatus in question.

If capacitors are connected to the system, an equivalent circuit can be drawn as in Figure 1 which will show these capacitors in parallel with an inductance representing the reactance of the supply source at the point where the capacitors are connected. This equivalent parallel combination is fed by the equivalent harmonic generator. If the parallel circuit has a resonant frequency near the frequency of one of the harmonics, the current in the capacitors may be much higher than the current from the equivalent harmonic generator and may overload the capacitors.

Capacitors are commonly designed with a voltage capability of 110 per cent of rated voltage and a kilovolt-ampere capability of 135 per cent of rated kilovolt-amperage. This margin in kilovolt-amperes permits the capacitor to carry a large harmonic current without damage. Figure 2 illustrates the harmonic current capability of capacitors at several harmonic frequencies.

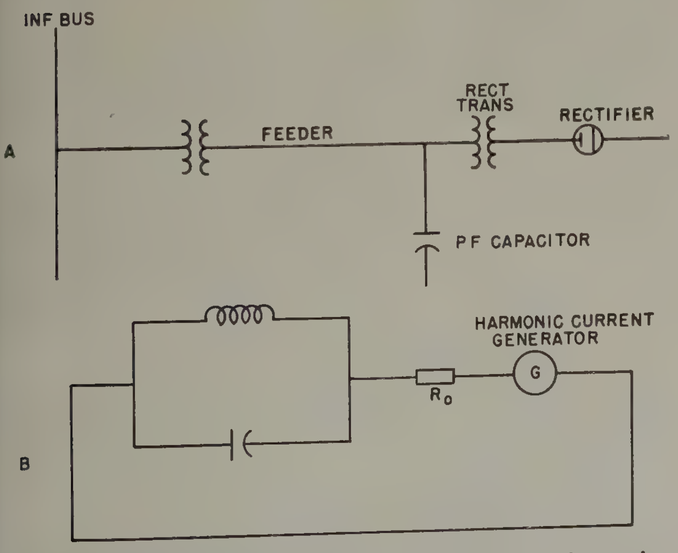

Figure 1. (A) Typical circuit diagram of rectifier and capacitor connected to a-c feeder. (B) Equivalent circuit for harmonic analysis

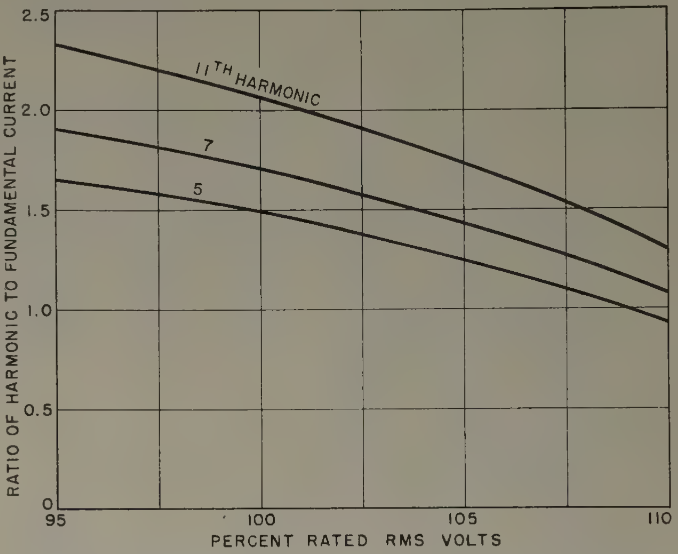

Figure 2. Harmonic current capabilities of capacitors with a single harmonic present

Typical 6-phase rectifiers introduce harmonic currents into the a-c system as follows:

Order of Harmonic	Harmonic Current, Per Cent of Fundamental
5	17–19
7	11–14
11	4–8

Remedial measures are often required if capacitors are connected to a system having harmonic current sources, particularly if resonance is present at or near one of the source harmonic frequencies. Remedial measures may take the following forms:

1. If trouble due to resonance is confined to a single frequency, the capacitors may be tuned with series inductance to that frequency, forming a low impedance trap which accepts most of the harmonic current available from the harmonic source.
2. Series reactors may be connected to all the capacitors, with a resulting resonant frequency less than that of any of the harmonics which are present.
3. Sometimes the only difficulty is blowing of capacitor protective fuses when these fuses are rated less than the harmonic current capability of the capacitors. Increase in fuse rating may solve the problem if care is taken not to overfuse the capacitors.

Digest of paper 53-24, "Capacitors in Power Systems With Rectifier Loads," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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Low-Frequency Self-Generated Oscillations in the D-C Carbon Arc

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A study of the fundamental properties of the d-c arc was undertaken starting with very low currents of 1 ampere or less and gradually increasing the current. Simultaneous observations of the variations in voltage, current, light, and sound produced by the arc were correlated with those controllable parameters in an attempt to understand better the basic processes involved.

UNDER THE sponsorship of the Office of Naval Research, the Department of Electrical Engineering of Johns Hopkins University has been conducting a study of the fundamental properties of the d-c arc. Particular attention has been given to arcs of higher current values (10 to 200 amperes) at atmospheric pressure, such as occur in welding, searchlights, circuit breakers, and so forth.

It long has been known that the voltage across such arcs is not always a steady d-c value. In many cases, particularly in welding operations, it is subject to wide random variations even though the voltage of the source supplying power to the arc remains perfectly steady. In the case of the carbon arc, the familiar "hissing arc" has been the subject of wide controversy and its mechanism is still in doubt.

In view of the importance of this behavior on the stability and utility of the arc, it was felt that a careful investigation of its nature was warranted. It was felt, also, that an understanding of the variations might lead to a better understanding of the basic arc processes for all types of arcs.

PLAN OF THE RESEARCH

THE PRIMARY PORTION of the study was devoted to the carbon arc, since variations in voltage and current occasioned by material transfer, such as occur in metallic arcs, would not be present with carbon electrodes. A search of the literature disclosed that one of the first thorough studies of the carbon arc was made by Ayrton[1] before 1900. More recent studies have been reported by Finkelnburg,[2] in which many important aspects of the carbon arc have been analyzed.

The studies to be reported here were made with solid projector-type carbons with anode and cathode of the same size and mounted with their axes in line. It was felt that this arrangement, while in some respects more difficult to work with, would lend itself more readily to analysis. The plan of research was to start at very low currents (1 ampere or less) and gradually increase the current to the hissing stage and beyond. At the same time, it was planned to make simultaneous observations of the variations (hereafter referred to as "oscillations") in voltage, current, light, and sound produced by the arc and correlate the results with those controllable parameters which might lead to a better understanding of the basic processes involved.

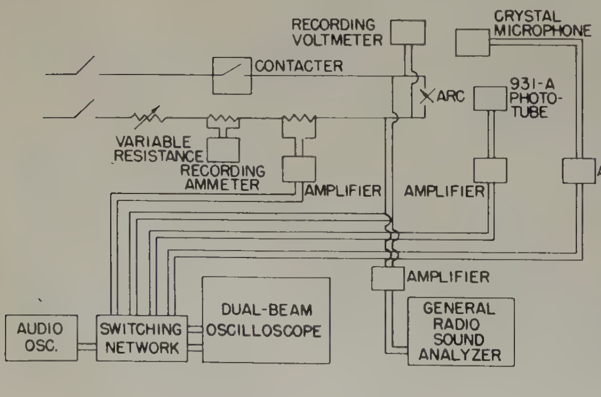

Figure 1. Diagram of apparatus for study of oscillations

EXPERIMENTAL APPARATUS

A DU MONT type *279* dual-beam oscilloscope was used to view simultaneously any two waveforms. The voltage waveforms were projected directly on the oscilloscope and a specially designed noninductive shunt was used to produce the voltage drops corresponding to the current waveforms. Light oscillations were detected by means of a Radio Corporation of America *931-A* phototube and sound oscillations were detected by means of a crystal microphone.

A 24-inch Navy Searchlight Chamber was used to enclose the arc for the studies in air. Average values of voltage and current were recorded on Esterline Angus recording meters.

A General Radio sound analyzer type *760-A*, with range extender as described by Cobine and Curry,[3] was used to measure the frequency of the oscillations up to about 1 megacycle. The measurement of the high-frequency oscillations covering the range above 1 megacycle was made using Hallicrafter superheterodyne radio receivers.

The measurement of arc length was made on an image of the arc magnified optically eight times and projected on a

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Revised text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953, and recommended for publication by the AIEE Committee on Electric Welding.

This article is Part I of a series of two articles on self-generated oscillations in the d-c carbon arc. Part II, "The Hissing Arc and Radio-Frequency Oscillations," will appear in a subsequent issue.

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The authors wish to acknowledge the advice and encouragement given them by Dr. W. B. Kouwenhoven, Dean of the School of Engineering, Johns Hopkins University.

calibrated scale. The arc length was defined as the minimum distance between the anode and cathode.

Power was supplied from a bank of Exide storage batteries capable of supplying 150 amperes at 100 volts for 8 hours. A schematic diagram of the apparatus arrangement is shown in Figure 1.

EXPERIMENTAL RESULTS

With solid carbon electrodes, it was found that if the current was increased slowly from very low values, by varying the external resistance of the circuit, there occurred a critical value of current at which oscillations of voltage, current, light, and sound were produced by the arc. These oscillations occurred at current values just below the hissing point and were of a low frequency, 50–400 cycles. They occurred over a very narrow current range under certain conditions of electrode shape. Since these low-frequency oscillations occurred in the quiet state of the arc, as contrasted with the hissing-state characteristic of higher currents, they were designated as "quiet oscillations," and will be referred to as such hereafter in this article. When the current was increased, the frequency of the quiet oscillations increased until a current was reached at which the arc began to hiss. The low-frequency oscillations then were displaced by the higher-frequency higher-amplitude random fluctuations which are characteristic of the hissing arc.

It was felt that a careful study of the quiet oscillations should be made since an understanding of their mechanism would provide a good groundwork for an analysis of oscillations in the hissing stage and beyond. Consequently, the remainder of this article will present the results of an analysis of the quiet oscillations; the results of studies made on the hissing arc and the high-frequency oscillations associated therewith are scheduled to appear in a subsequent issue.

The quiet oscillations were found to be superimposed on the steady d-c waveforms of current and voltage. The oscillations were of nearly sinusoidal waveform and were smooth and continuous as contrasted to the waveforms of voltage extinctions described by Finkelnburg[2]. The first point of study was to determine if the frequency or occurrence of the oscillations was connected in any way with the inductance or capacitance associated with the external circuits supplying power to the arc. Various values of inductance and capacitance were connected both singly and in combination across the arc, and inductance was connected in series with the arc. None of these reactances affected the oscillations either in frequency, waveform, or any other characteristic.

VOLTAGE OSCILLATIONS

It was found that, for a given size electrode and given arc length, the frequency of the voltage oscillations increased as the current was increased up to the point at which the arc began to hiss. Then the quiet oscillations were no longer observed. The relations between the frequency of the voltage oscillations and the value of arc current for several values of arc length are shown in Figure 2 for electrodes of 9-millimeter (3/8-inch) diameter. Figure 3 shows the relation between oscillation frequency and arc current for an arc length of 3/40 inch and for three different diameter electrodes. It is seen that both electrode size and arc length have an effect on the frequency of the oscillations.

Figure 2. Correlation between measured and calculated values of frequency of quiet oscillations for 3/8-inch electrodes

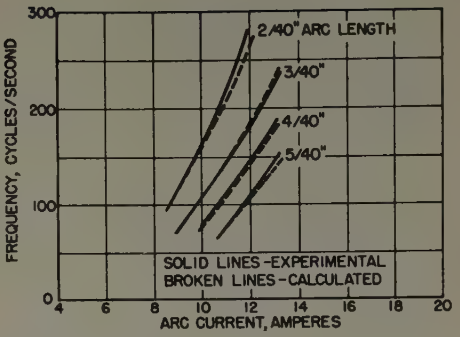
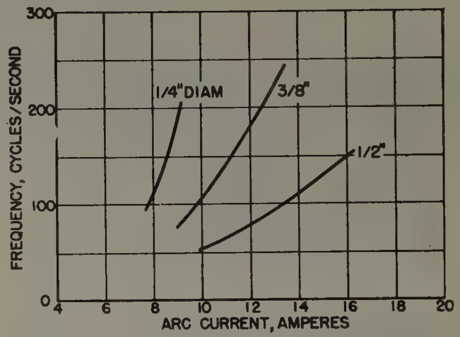


Figure 3. Measured variation of frequency of quiet oscillations with current for 3/40-inch arc length



The arc was started in each case with the anode flat as shown in Figure 4*A*. After the arc had burned about 5 minutes at the arc length and current at which measurements were to be made, the electrodes assumed the shape shown in Figure 4*B*. Until the anode had reached the form shown in Figure 4*B*, no oscillations of a stable nature could be obtained. However, after the electrodes reached that shape, the oscillations were relatively stable and the electrodes maintained this shape. The frequency increases as the arc current is increased as shown in Figure 3, but the rate of increase becomes less as the diameter of the electrodes increases. The amplitude of the oscillations increases as the current is increased up to a value of about 3 volts, at which point the arc begins to hiss.

CURRENT OSCILLATIONS

Current oscillations of the same frequency and waveform, but 180 degrees out of phase with the voltage oscillations, were found to be present. A series of photographs of voltage and current oscillations, taken with a Leica 35-millimeter camera from the Du Mont dual-beam oscilloscope, is shown in Figure 5. These oscillations occurred in an arc with 9-millimeter-diameter electrodes, 3/40-inch arc length, and currents ranging from 9 to 12 amperes. The photographs show clearly that there is a 180-degree phase shift between the voltage and current oscillations. This 180-degree phase difference between current and voltage oscillations is to be expected, since the quiet oscillations take place on the negative resistance portion of the voltage-current characteristic of the arc.

Figure 6 shows the approximate variation of arc voltage with arc current for 9-millimeter electrodes and various

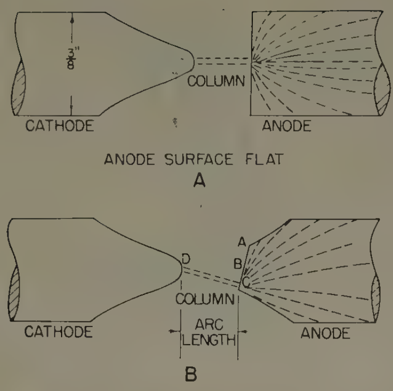


Figure 4. Sketch of anode and cathode showing current flow in anode

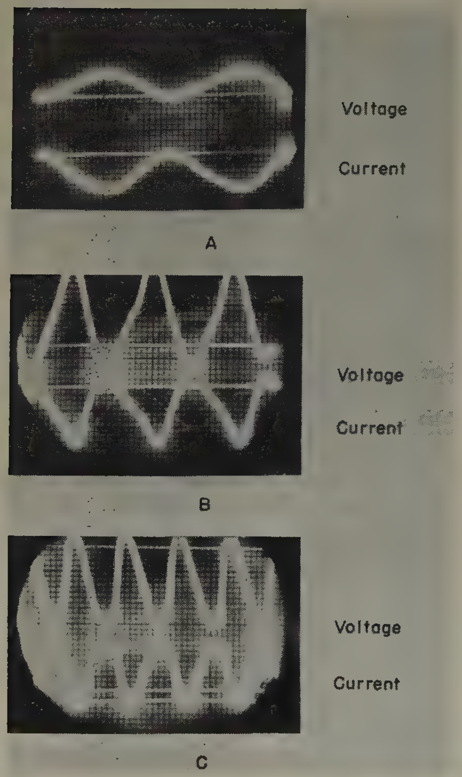


Figure 5. Voltage and current oscillation waveforms for 3/8-inch electrodes, 3/40-inch arc length

values of arc length. The curves show that at low currents, the voltage decreases as the current is increased; that is, that the arc behaves like a negative resistance until a definite current is reached, at which point the arc begins to hiss and the arc voltage abruptly drops 10 volts. A comparison of Figures 2 and 6 shows that the quiet oscillations occur in the current range just below the point at which the arc begins to hiss.

LIGHT OSCILLATIONS

Figure 7 shows typical photographs of the voltage trace (top) and the light trace (bottom) for 9-millimeter electrodes, 3/40-inch arc length, and current about 12 amperes. The three photographs were taken with the same current and arc length, the only difference being the region of the anode from which the light was taken. Figure 7*A* was taken with the phototube aperture focused on the edge of the anode crater at the top looking at the cross section of the arc (point *A* in Figure 4*B*). Figure 7*B* was taken with the aperture focused on the edge of the crater in the middle (point *B* of Figure 4*B*). Figure 7*C* was taken with the aperture focused on the edge of the crater of the bottom (point *C* in Figure 4*B*). In Figure 7*A*, the voltage and light oscillations are almost exactly in phase. In Figure 7*B*, the light lags the voltage about 90 degrees, and in Figure 7*C* the light is 180 degrees out of phase with the voltage. This variation of 180 degrees in phase between the light and the voltage oscillations was observed at all times when the arc was in the quiet-oscillation region, and the light was observed from the bottom of the anode. The reason for this phase shift will be explained later. Figure 8 shows a series of photographs taken at the bottom of the anode crater for the same conditions of electrode size and arc length, but with increasing values of current. Figure 8*D* was taken at a current just below the hissing point. Both the voltage and light waveforms have changed from periodic waves to random variation. At a slightly higher current, the arc begins to hiss, Figure 8*E*. The voltage waveform now appears as a high-frequency hash on the scope while the light oscillations appear as random fluctuations. The amplitude of the hissing voltage measured on the scope was about 10 volts and was independent of the current.

HIGH-SPEED MOTION PICTURES

High-speed motion pictures, 3,000 frames per second, were taken to determine what effects were taking place in the arc during the quiet oscillations. An Eastman Kodak high-speed camera was used with Super *XX* film with an aperture of *f8* and a red filter, Corning number *2418*. The red filter was used to accentuate the effects at the anode surface and suppress the light from the column, which is predominantly blue. The film showed clearly the rotation of a bright spot of light around the outer circumference of the anode crater. A neon timing light built into the high-speed camera was used to provide a 1/120-second timing pulse on the film. The frequency of rotation of the spot thus could be determined. The frequency of rotation was found to be exactly equal to the frequency of the quiet oscillation observed on the oscilloscope at the time the motion pictures were taken.

MECHANISM OF QUIET OSCILLATIONS

Explanation of Observed Results. The high-speed motion pictures show conclusively that there is a connection between the oscillations of voltage, current, light, and sound, and the rotation of the anode spot. A possible cause of the variation in arc voltage would be a variation in arc length as the spot rotates around the anode crater. An analysis of Figure 4*B* shows that such a variation in arc length exists, and that the difference in arc length between top and bottom is the order of 1/64 inch. To determine whether variations in arc length can account for the variations in arc voltage, it is necessary to determine the potential gradient of the column. The potential gradient of the arc column can be determined from the data of Figure 6, and is approximately 160 volts per inch. A variation of 1/64 inch in arc length, therefore, would produce a change of 2.5 volts in arc voltage. This is of the same order of magnitude as obtained from measurements of the voltage oscillations on the dual-beam oscilloscope. Thus, the voltage oscillations appear to be caused by the rotation of the anode spot with a corresponding periodic change in arc length. The current oscillation would follow as a natural result of the changes in voltage and the negative resistance characteristic of the arc.

The 180-degree phase shift of the light oscillations with respect to the voltage across the anode crater now can be explained. Figure 4*B* shows a scale drawing of the electrodes as they appear when the arc is in the quiet-oscillation range. The arc length may be either *DA* when the spot is at the top of the crater, *DC* when it is at the bottom, or any length between these values. As shown in the diagram, *DC* is less than *DA*. Suppose the voltage oscillations are impressed upon one section of the dual-beam oscilloscope and the light oscillations on the other section, and the aperture of the phototube is focused on point *A* of the crater: the voltage then will be a maximum when the anode spot is at point *A*. One-half cycle later, the anode spot will be at point *C*. The voltage and light will be a minimum, since the phototube is still focused on point *A*, while the bright spot of light has moved. Hence, the voltage and light oscillations will be in phase. If the phototube aperture is focused on point *C*, the voltage will be a minimum when the spot is at *C*, but the light will be a maximum. One-half cycle later, when the spot is at *A*, the voltage will be a maximum, and the light will be a minimum. Thus, the voltage and light will be 180 degrees out of phase when the phototube is focused on the bottom of the anode crater and they will be in phase when the phototube is focused on the top of the crater. When the phototube aperture is focused on the middle of the crater, the phase difference will be 90 electrical degrees. This explanation is consistent with Figure 7 which shows the voltage and light in phase at the top of the crater, 90 degrees out of phase in the middle of the crater, and 180 degrees out of phase at the bottom of the crater. The quiet oscillations, therefore, are the result of the rotation of the anode spot around the anode crater.

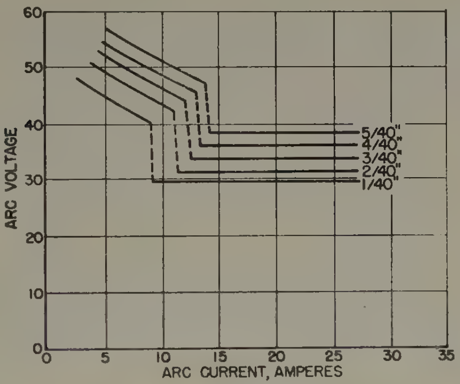
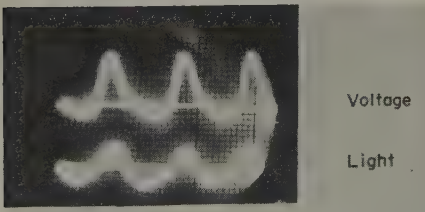
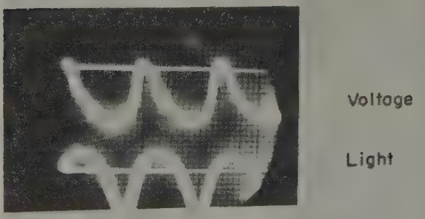


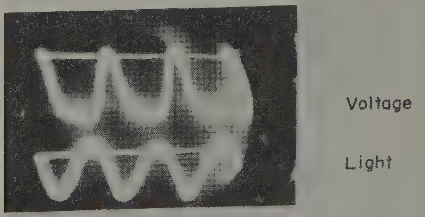
Figure 6. Voltage-current characteristics of carbon arc in air, 3/8-inch electrodes



A Light From Top of Anode

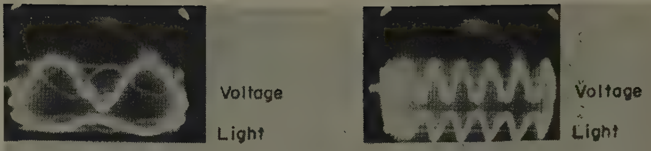


B Light From Middle of Anode



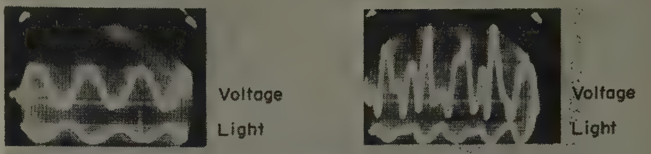
C Light From Bottom of Anode

Figure 7. Voltage and light oscillation waveforms for 3/8-inch electrodes, 3/40-inch arc length, 12 amperes



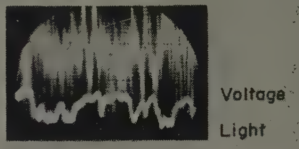
A 8.5 amperes

C 12.5 amperes



B 11 amperes

D 12.7 amperes



E 12.9 amperes

Figure 8. Voltage and light oscillation waveforms, 3/8-inch electrodes, 3/40- inch arc length

Cause of Rotation. The cause of the rotation is now to be determined. It is known that a beam of electrons in a transverse magnetic field will be acted on by a force which will tend to move it in a direction perpendicular to both the direction of the field and the direction of the beam. Such a motion will be circular. The arc current can be considered to be a concentrated beam of electrons and ions, but mostly electrons. The concentration of electrons is particularly large near the anode. When the current enters the anode spot which is small in comparsion with the anode crater, the current will tend to spread out to form flow lines as shown in Figure 4. Such a distribution of current as in Figure 4 will produce a transverse component of magnetic field at the crater surface. Thus, there will be a tendency for the arc column to rotate. The strength of the magnetic field will depend upon the value of the current and the degree of dissymmetry present at the anode crater. With an electrode which was cut with a perfectly flat face perpendicular to the electrode axis, there would be no transverse component of magnetic field, as in Figure 4*A*. This fact explains why there are no quiet oscillations when the arc is first started with flat electrodes, and why the oscillations become more and more firmly established as the

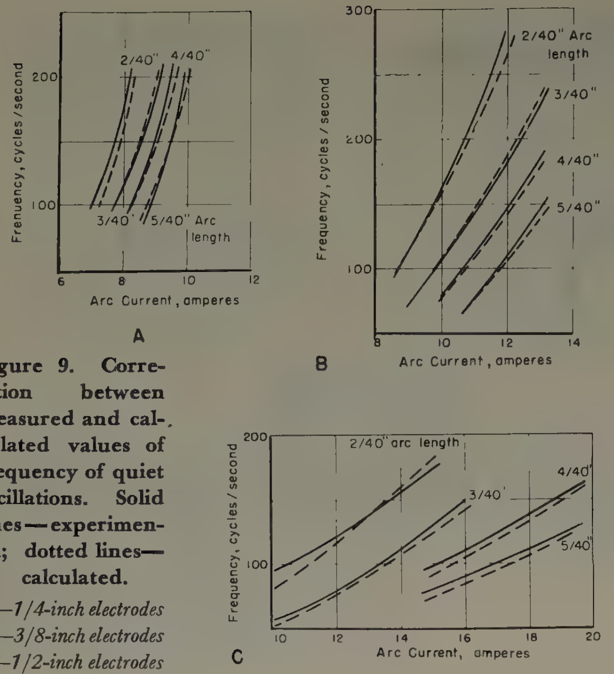


Figure 9. Correlation between measured and calculated values of frequency of quiet oscillations. Solid lines—experimental; dotted lines—calculated.

A—1/4-inch electrodes
B—3/8-inch electrodes
C—1/2-inch electrodes

electrodes burn so as to attain the final shape. The shape of the anode is the critical factor, and the shape of the cathode tip seems to make no difference. The oscillations will occur with a flat cathode and an anode which has burned to the shape shown in Figure 4*B*. The anode attains this shape as a result of the fact that the heat rises by convection and causes more rapid burning at the top of the electrode.

Effects of External Fields. In order to determine the effects of various types of magnetic fields on the oscillations, several experiments were conducted. The arc was burned in the presence of an external radial magnetic field. When the external field was in such a direction as to add to the arc's magnetic field, quiet oscillations and hissing occurred at a lower current than without the field. If the magnetic field were reversed so as to oppose the arc's field, quiet oscillations and hissing occurred at a higher current than without the field.

The effect of an axial magnetic field was to increase the amplitude of the quiet oscillations without affecting their frequency. The amplitude of the quiet oscillations increased linearly with magnetic-field strength.

The effect of a transverse magnetic field was to increase the frequency of the quiet oscillations with no effect on the amplitude if the external field were in such a direction as to aid the transverse component of magnetic field produced by the arc. If the external transverse field were reversed, so as to oppose the field produced by the arc, the frequency of oscillation decreased as the field was increased. These studies show clearly that a magnetic field has significant effect on the quiet oscillations and actually can cause them to occur at currents below which they would occur normally. This serves to substantiate the explanation of the cause of the oscillations given previously.

THEORETICAL EXPLANATION OF QUIET OSCILLATIONS

THE DETERMINATION OF an empirical relation between the frequency of oscillation and the arc current was desired. Such a determination can be made by making several assumptions which have been fairly well established in the arc field. Considering that the arc column is essentially a concentrated beam of electrons, such that it can be thought of as a cylinder rotating through the arc atmosphere, the following equation was developed:

$$f = CI^{2n+1}/Rrl_2$$

where C and n are constants depending upon the electrode diameter; I is the arc current in amperes; R is the radius of the arc column; r is the radius of rotation of the anode spot; and l_2 is the arc length.

The comparison between the measured values of the frequencies of the quiet oscillations and the calculated values from this empirical equation are shown in Figure 9, for three sizes of electrodes.

Tests With Other Types of Electrodes. Attempts were made to obtain quiet oscillations with electrodes other than the National Carbon Company solid projector carbons used in all the work thus far reported. No other electrode produced oscillations as stable as those with carbon. Graphite electrodes produced hissing with no noticeable region of quiet oscillation before hissing began. Copper, aluminum, and tungsten electrodes showed a region of voltage fluctuation before hissing began, but there were no stable oscillations that could be studied as in the case of carbon.

CONCLUSIONS

THE RESULTS of this research may be summarized as follows:

1. A study of the d-c arc in air at normal temperatures and pressures between solid carbon electrodes has disclosed the presence of symmetrical, uniform oscillations of current, voltage, light, and sound occurring at current values just below the hissing stage.
2. The oscillations are of low frequency in the range 50 to 400 cycles.
3. The oscillations occur with high uniformity only after the anode tip has attained its characteristic shape.
4. The frequency of the oscillations is affected by the material, diameter, and separation of the electrodes and by the arc current, but not by reactance present in the power supply.
5. The oscillations are caused by rotation of the anode spot about the periphery of the anode due to the presence of an unsymmetrical magnetic field caused by the arc current itself at the anode surface.
6. An empirical equation has been developed to express the frequency of the oscillations as a function of current and electrode parameters.
7. It is believed that the behavior of the anode spot and the influence of the arc's own magnetic field as reported here have a direct bearing on the initiation of the "hissing" arc and on its characteristics.

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Voltage Regulation of 12-Phase Double-Way Rectifiers

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TWELVE-PHASE rectification obtained by connecting two double-way rectifiers in series on the d-c side is often employed in special applications requiring high direct voltages. The customary practice is to supply the rectifiers from two 3-phase transformer banks in parallel on the a-c side, one bank connected Y-delta, the other delta-delta. Operation of such rectifiers is affected to a greater extent by common a-c reactance than is operation of 6-phase rectifiers.

Conventional methods of calculating rectifier voltage regulation are valid only if the angle of overlap is less than 360 degrees divided by the number of phases. At larger angles of overlap an inherent delay angle, introduced by a-c reactance common to two or more simple rectifiers, reduces the direct voltage and thereby increases the voltage regulation.

There are five modes of operation in the 12-phase rectifier as load is increased from zero to the short-circuit value. In the first mode of operation, as load current is increased from no load, the commutating or overlap angle (u) increases from zero to 30 degrees. During the second mode of operation, the commutating angle is fixed at 30 degrees, but the start of commutation is delayed by an inherent delay angle (α) which varies from zero to some maximum value (α_m) as the rectifier supplies increasing load current. Operation in the second mode is quite similar to 6-phase operation where leakage reactance between secondary windings is not negligible. The maximum value of the delay angle is calculated from the equation

$$\tan \alpha_m = \frac{k\sqrt{3}}{4-3k} \qquad (1)$$

where k is the ratio of reactance common to both 6-phase rectifiers to total commutating reactance. The angle of inherent delay does not change during the third mode while the commutating angle increases from 30 to 60 degrees. During the fourth mode of operation, the commutating angle is fixed at 60 degrees, and the start of commutation is delayed by a second angle of delay (β), which increases from zero to 30 degrees. In the fifth mode the total angle of delay ($\alpha_m+\beta$) is fixed while the commutating angle increases from 60 to $(120-2\alpha_m)$ degrees at short circuit.

The ratio of direct voltage to no-load direct voltage (E_d/E_{do}) is plotted against reactance factors in Figure 1. These curves show that voltage regulation increases as the ratio of common to total reactance becomes larger.

The trend of the calculated regulation curves was substantiated by tests on a model rectifier on the analogue computer, or Anacom. Data taken on the Anacom circuit are shown as test points in Figure 1. These data have been corrected for voltage drop across the rectifying elements and for losses in the circuit elements. Although the trend of the calculated curves was substantiated by Anacom data, there is some discrepancy between the laboratory data and the theoretical curves at the higher ratios of common to total reactance.

One handicap lay in the construction of the Anacom transformers. These transformers are provided with a variable turns ratio in 10-per-cent steps. Therefore, the delta-delta transformer bank could be set up with a 100-per-cent turns ratio, but the turns ratio of the Y-delta bank had to be set up with a 60-per-cent turns ratio instead of the desired 57.7 per cent. Some inaccuracies were introduced into the laboratory curves by the method employed to account for losses in the computer circuit elements. Data taken from the Anacom were first corrected for tube drop corresponding to the load current. Then corrections were made for resistance drop by dividing the watts loss in the a-c circuit by the current in the d-c circuit, the conventional procedure of correcting for a-c circuit losses in rectifiers. The accuracy of this method depends upon how closely the current waveforms approach theoretical shapes. These two factors, lack of the exact transformer turns ratio required and variation of the current wave from the exact theoretical shape, account for the differences between calculated curves and laboratory data.

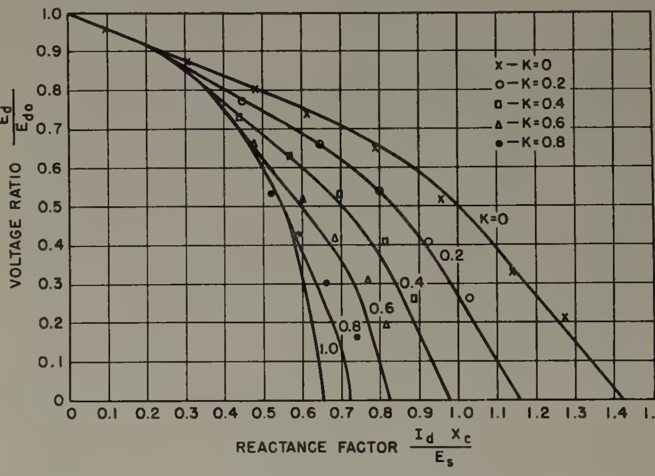

Figure 1. Voltage regulation curves for 12-phase double-way rectifier showing laboratory data

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Digest of paper **53-242**, "Voltage Regulation of 12-Phase Double-Way Rectifiers," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 15–19, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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Transformer Models Determine Transient Voltages

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SPACE OCCUPIED BY INSULATION profoundly affects the over-all transformer size and weight, and the cost. The insulation itself is expensive, takes space, and interferes with other functions, as for instance, removal of heat from core and coils, and increases reactance. More important, however, is the fact that additional amounts of copper and iron are required in a transformer because of the space taken up by insulation. For these reasons, in large high-voltage power transformers large dividends, in size, weight, and cost reductions, and in the improvement of some operating characteristics, are obtained by designing the insulation more precisely as to location and amount.

Required transformer insulation is determined to a great extent by the transient voltages which appear in the transformer windings. These voltages may be caused by lightning, switching surges, or by commercial factory impulse tests. To design the insulation correctly, it is necessary to know two things: (1) the voltage (as a function of time) appearing across the insulation, and (2) the strength of the insulation for that particular voltage wave shape. These two items are equally important, but item 1 is required first and will be discussed in this article.

It is impractical to compute by purely analytical means all the transient voltages appearing in the increasingly complicated present-day transformer. For this reason the transformer electromagnetic model was developed, which furnishes directly complete, accurate knowledge of the transformer transient voltages in a short time. The electromagnetic model consists of two parts:

1. An equivalent circuit of capacitances of scale factor C.
2. A geometrical model for the self and mutual inductances, even if nonlinear, of scale factor L.

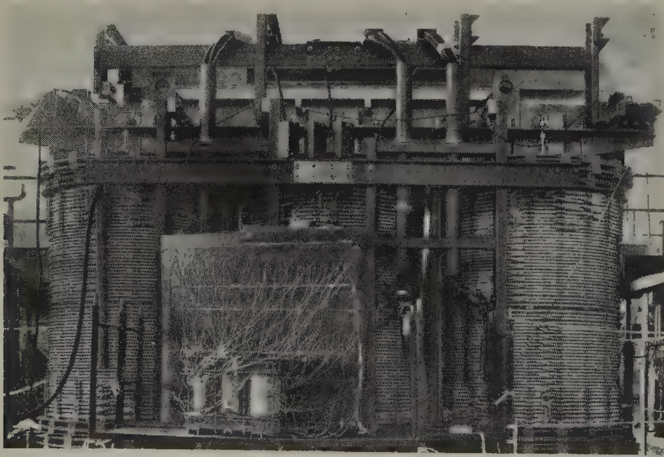

Figure 1. 3-phase transformer, 30,000 kva, 138,000 kv, delta-connected to 69,000 kv Y-connected and its electromagnetic model (scale of lengths 1:8)

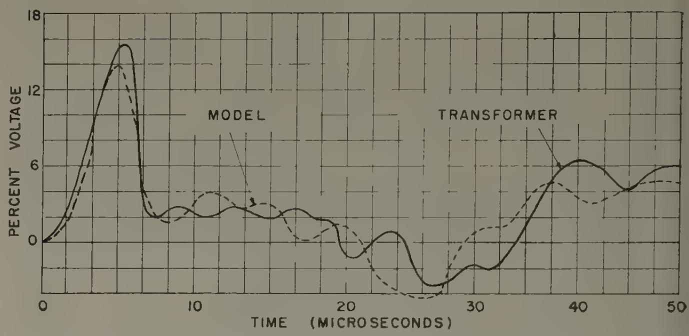

Figure 2. Full-wave voltages across 13th duct from line of impulsed high-voltage winding of 30,000-kva, 138-kv to 69-kv transformer and its electromagnetic model

For nonlinear inductances, the iron core also is scaled geometrically, and with the appropriate voltage scale it has the same values of magnetic characteristics B, H, and μ at corresponding points and times as the original. In order to minimize the effect of frequency on the model characteristics, it is convenient to use a time scale not too different from unity.

The transformer capacitances must be known. It is relatively simple to compute them in most cases. In fact, for many years a calculating board has been used to determine the electrostatic voltage distribution in transformer windings. Whenever the capacitances are difficult to compute, they may be determined by field plotting, with the electrolytic tank, and similar means.

A 3-phase transformer, rated 30,000 kva, 138 kv (delta-connected) to 69 kv (Y-connected) is shown together with its model, of length scale 1:8, in Figure 1. The full-wave voltages across the 13th duct, which encompasses 3.2-per-cent winding, of the impulsed high-voltage winding are shown in Figure 2. On 11 models built in 1950 and 1951, 238 measurements of the maximum voltages between corresponding points of the models and of the original transformers showed an average absolute deviation equal to 4.3 per cent of the applied wave and to 9.8 per cent of the transformer voltage at the points measured. Electromagnetic models now are being used extensively for the design and development of power transformers. Models also are used to study transformers as components of a power system.

Digest of paper 53-132, "Transformer Models for the Determination of Transient Voltages," recommended by the AIEE Committee on Transformers and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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The development of the electromagnetic model could not have taken place without the active help, encouragement, and criticisms of many of the author's associates in the General Electric Company, in particular K. K. Paluev, D. D. MacCarthy, J. R. Meador, I. B. Johnson, and A. F. Rohlfs. All tests on the models and on the original transformers were done by the staff of the High Voltage Engineering Laboratory.

A Sensitive Direct-Writing Plethysmograph

TRAVIS WINSOR

A detailed description of this new simple pneumoplethysmograph utilizing an electronic transducer is presented. It is valuable in clinical work as it can record systolic blood pressure at various points on the extremities, volume pulsations of the toe or finger, relative blood flow, potential blood flow, peripheral resistance, vasomotor activity, and other vascular phenomena.

A PLETHYSMOGRAPH (Greek *Plethysmos*—increase; *graphikos*—to write) is an instrument which records volume changes of living tissues. As these changes are due to variations in blood flow, this instrument, by recording these changes in volume, provides an objective means of studying the circulation of blood through various parts of the body. The plethysmograph was first described in 1732[1] and the early work in this field was done by physiologists who applied the principles of plethysmography[2] to the study of various animal structures such as the kidney, heart, tail, paw, and other tissues. By recording the blood flow, it has been possible to study the circulation of blood through these tissues in detail and thus to understand better their physiology. In a general way, the plethysmographic technique involves the sealing of a finger or toe within a capsule from which volume changes are transmitted through a hydro[3] or pneumatic system[4] to suitable recording equipment.

In the practice of medicine, the plethysmograph is used to determine the amount and manner of blood flow through the extremities of normal and diseased individuals and thus is useful as a diagnostic tool. This instrument makes it possible to determine if disease of the arteries is present, and helps in selecting the patients who may be benefited by various surgical procedures directed toward increasing the circulation to diseased fingers or toes. The plethysmograph can help to locate obstructions at various points in the arterial tree. One may assess the effectiveness of medical treatment, the rate of regrowth of nerves after they have been removed by the surgeon for the purpose of increasing the blood flow, and an individual's sensitivity to tobacco. The results obtained from the plethysmographic examination assist in clarifying such symptoms of the extremities as pains, cramps, coldness, weakness, ulcers, and gangrene.

DESCRIPTION OF THE INSTRUMENT

Principle of Operation. The finger or toe under investigation is enclosed in an airtight cup of constant volume. Volume changes of the part are transmitted pneumatically to a distensible metal capsule through nondistensible flexible tubing, see Figure 1. Movement of the capsule produces movement of the plate of a vacuum tube which varies the output of the electric circuit. This variation is recorded by means of a d-c amplifier using a heated stylus or ink-writing recorder, see Figure 2. Proper calibration permits quantitative determination of volume changes of the digit under study.

The Pneumatic System. The plethysmographic digital cup is of acetate with an exact volume of 14 cubic centimeters. The inside diameter is 20 millimeters, and the outside diameter is 22 millimeters. The outlet of the cup has a 1-millimeter bore. The base of the cup is fitted with an acetate plate which contains an eccentric orifice to admit the digit. Cups containing orifice diameters of 15, 16, 17, 18, and 19 millimeters are suitable to admit the index finger or second toe of most adult subjects. Cups with smaller orifices may be adapted easily to digits of unusual form or size with the aid of a rat-tail file.

The connecting tubes between the digital cup and the lead selector valve of the plethysmograph are 7 feet long and consist of flexible, nondistensible tubing of plastic or rubber with a 1-millimeter inside diameter. A 1-millimeter bore is of such a size that condensation of water within the tubes does not occur readily and the volume of the dead space in the pneumatic system is not increased materially. It is important that no elastic tubing be present in the system as even 3 or 4 inches have sufficient

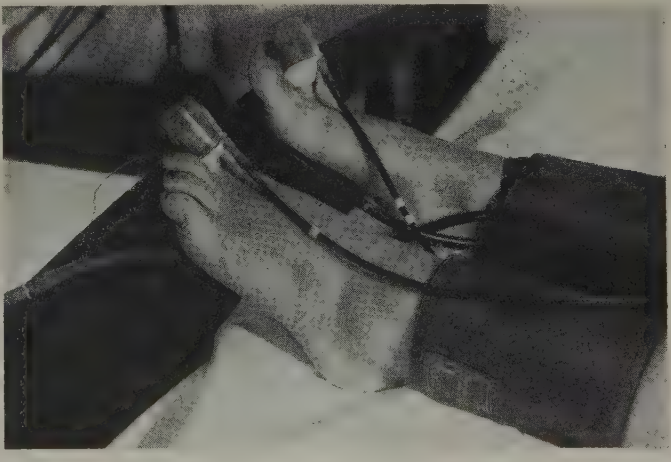

Figure 1. Digital cups on second toes, with venous occluding cuffs in place

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Revised text of a conference paper presented at the AIEE Pacific General Meeting, Phoenix, Ariz., August 19–22, 1952, and recommended for publication by the AIEE Committee on Electrical Techniques in Medicine and Biology.

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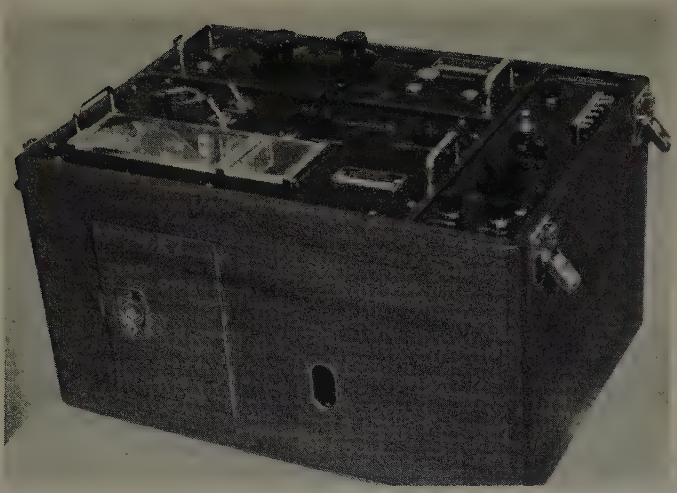

Figure 2. Electronic plethysmograph, mounted in a Sanborn industrial-type direct-writing recorder. The six input ports and the 6-way lead selector valve allow consecutive plethysmographic readings to be made from six digits of the extremities

damping effect to alter the volume pulse curve of the plethysmogram. The internal construction of the pneumatic system is such that unnecessary differences in orifices and tube diameters are avoided to minimize distortion of the curves due to turbulence.

The lead selector valve has six ports, making it possible to record consecutively from six regions of the body by changing the switch position, see Figure 3. All inactive ports are open to the atmosphere to avoid pressure changes in the unused portions of the system. The valve is constructed so that dead space in the pneumatic system is minimal.

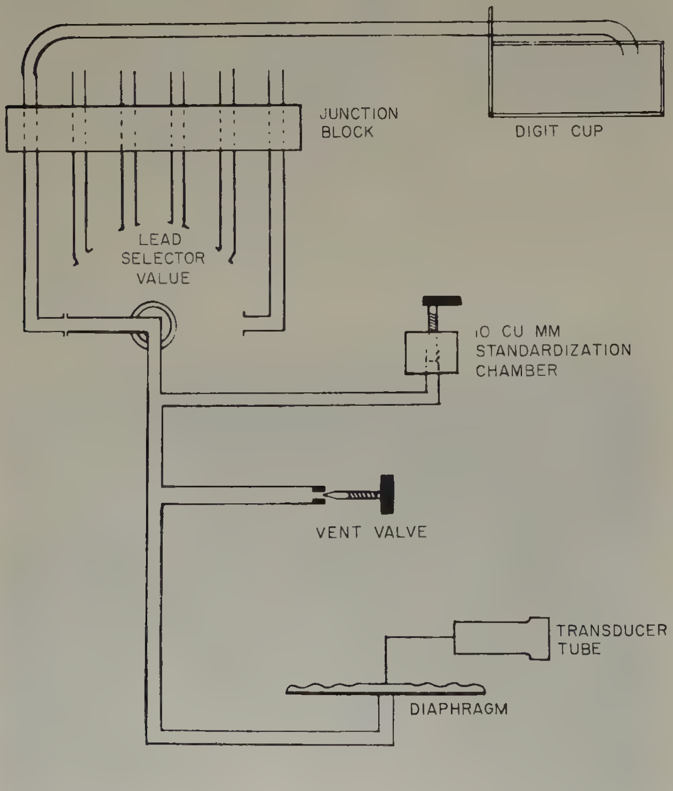

Figure 3. Schematic diagram of the pneumatic circuit. The transducer is shown coupled to the diaphragm of the pneumatic system by the movable pin of the tube

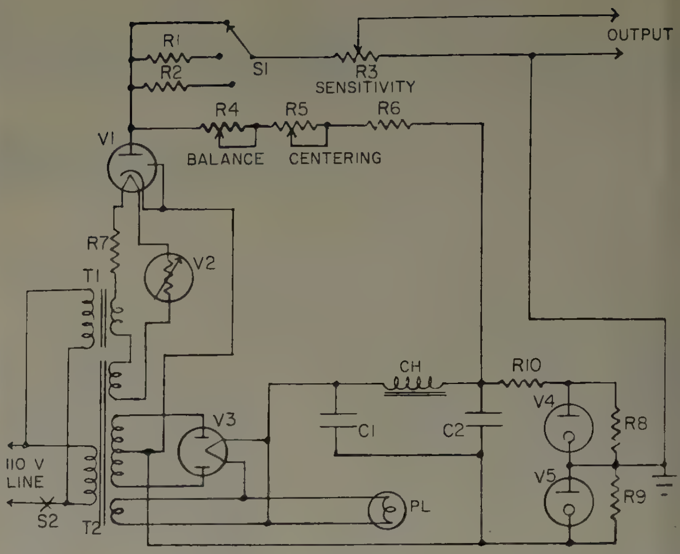

Figure 4. The electronic circuit: T1: 6.3-volt filament transformer. T2: 240-0-240 at 40 milliamperes, 6.3- and 5-volt power transformer. CH: 50-milliampere choke coil. C1 and C2: 8 microfarads per 450 volts. R1: 0.27 megohm, $^1/_2$ watt. R2: 0.75 megohm, $^1/_2$ watt. R3: 0.25-megohm potentiometer. R4: 25,000-ohm potentiometer. R5: 15,000-ohm potentiometer. R6: 100,000 ohms, $^1/_2$ watt. R7: 10 ohms, 1 watt. R8 and R9: 33,000 ohms, 1 watt. V1: RCA 5734. V2: Amperite 1HT4. V3: 5Y3. V4 and V5: OB2. S1: 3-position tap switch. S2: single-pole single-throw rotary switch. PL: 6.3-volt pilot lamp. R10: 10,000 ohms, 25-watt adjustable wound wire; adjusted so that OB2's draw 15 milliamperes

The calibrating bellows, made of brass and measuring 25 by 35 millimeters, is firmly fixed at one end so that compression by means of the calibrating lever delivers exactly 10 cubic millimeters of air into the pneumatic system of the instrument. A spring attached to the lever automatically returns it to its original position, thus restoring the bellows to its initial volume. This system produces an accurate and reproducible calibration. The degree of amplification can be adjusted so that the sensitivity of the instrument can be varied.

The transducer is a metal capsule with a thin brass membrane. The capsule is fixed in such a manner that the membrane is free to expand or contract in an axial direction to accommodate changes in volume. The Radio Corporation of America transducer tube is fixed firmly adjacent to the membrane which in turn is coupled to the plate of the tube so that movement of the pin outside the tube results in movement of the plate inside the tube. The transducer links the pneumatic to the electric system.

Electronic System. The wiring diagram of the plethysmograph is shown in Figure 4. The amplifying system consists of a d-c amplifier. This was chosen to record the slow (beta) waves as well as the rapid (pulse) waves of the plethysmogram (0.8 to 160 cycles per minute).[5,6] This type of amplifier is found in most direct-writing electrocardiographic machines. Certain of these instruments are equipped with an input jack which by-passes the preamplifier and leads directly to the d-c amplifier. If this is not present, the installation of such a jack is a simple

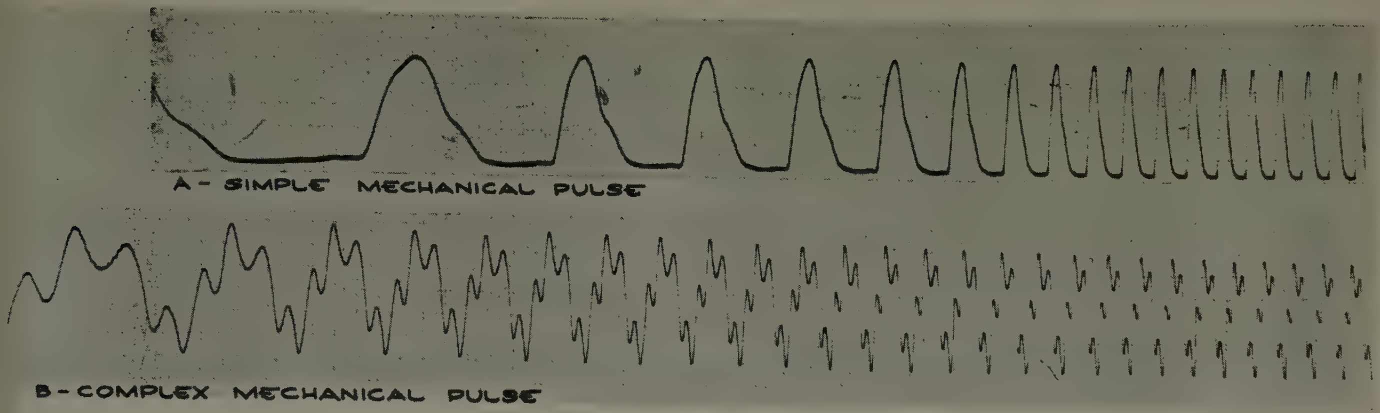

Figure 5. Response of the plethysmograph to a mechanically induced pulse wave which is (A) simple in contour and (B) complex. The frequency response of the instrument is adequate for the accurate recording of such frequencies as are encountered in plethysmography

matter. Either a heated-stylus or ink-writing recorder is satisfactory.

Specification. The maximum sensitivity of the electronic pneumoplethysmograph is a 50-millimeter movement of the stylus for a 5-cubic-millimeter volume change in the pneumatic system. This is high, compared with other commercially available plethysmographs. The importance of this added sensitivity can be seen when patients with advanced peripheral vascular disease are studied. In these patients, measurements with the electronic instrument are possible when no measurable pulsations or flow can be detected with a less sensitive instrument. Thus, greater accuracy in plethysmographic interpretation can be achieved.

The frequency response of this instrument was tested by a mechanically induced volume change which resulted in the writing of a simple wave resembling a pulse wave which showed less than 2 per cent decrease in amplitude of the wave at 5 cycles. When a complex volume change was introduced, the height of the waves fell off 13 per cent at 15 cycles. This would be considered an adequate, rapid frequency response for plethysmography, see Figure 5.

The paper speeds are 25 and 2.5 millimeters per second. The former is the standard electrocardiographic paper speed and is desirable for recording volume pulsations of the finger or toe, the rate of blood flow, potential flow, peripheral resistance, and the systolic blood pressure of the extremities. Slow paper speeds are desirable for recording induced and spontaneous vasomotor activity, see Figure 6. Most standard electrocardiographic machines may be fitted with a suitable gear box which effects a 10 times reduction in paper speed, making both speeds possible.

The volume-pressure relationship shows an increase in pressure of 0.5 millimeter of water as measured by a specially designed water manometer when the volume is increased 50 cubic millimeters. This indicates that the instrument is primarily a volume recorder.

The stylus drift does not exceed 0.6 millimeter per minute at standard sensitivity after the instrument has been turned on for 20 minutes.

The deflection of the stylus to a 50-cubic-millimeter induced volume change is accurate, within 5 per cent, at normal standardization.

The noise level of the system is negligible and the microphonic interference has been reduced to a minimum by shock mounting.

DISCUSSION

THE CRITERIA FOR a satisfactory pneumoplethysmograph, carefully considered before construction of this instrument, were as follows:

1. Accurate recording of volume changes of finger or

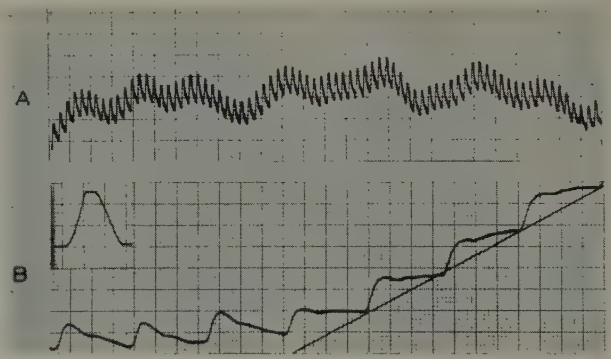

Figure 6. Waveforms of the plethysmogram:

(A) Slow record with a paper speed of 2.5 millimeters per second. Horizontal lines are 1 millimeter apart and, when the instrument is properly standardized, represent 1 cubic millimeter of volume change per 4 cubic centimeters of digit. Vertical lines are spaced 1 millimeter apart and represent a 0.4-second time interval. Each spike or pip on the plethysmogram is the pulse wave which represents a volume change resulting from mechanical constriction of the heart. For each six pulse waves there is a slower wave, a respiration wave, which represents the mechanical effects of changes in intrathoracic pressure with breathing. Slower waves, occurring from four to one times a minute, are called alpha or beta waves and represent for the most part changes in volume due to activity of the sympathetic nervous system. These various waveforms are of importance in determining the state of the peripheral circulation and in ruling in or out the presence of arterial disease

(B) Standardization, the detailed characteristics of the pulse wave, and a venous congestion test. The latter is performed to determine the relative rate of blood flow through a digit. The paper speed is 25 millimeters per second. The distance between vertical lines is 1 millimeter, representing a duration of 0.04 second. The relative rate of blood flow is measured by determining the volume change in 1 second of time

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toetip, with minimal change of pressure in the pneumatic system, that is, for a 50-cubic-millimeter volume change (50-millimeter deflection of the stylus) the pressure in the pneumatic system, including the digit, should change 0.5 millimeter of water, or less.

2. Accurate standardization against a known volume, 10 cubic millimeters of air.
3. Faithful reproduction of the pulse-wave contour of a normally pulsating digit as compared with the record obtained from such a digit by photographing the movement of fluid in a pipette.
4. High sensitivity, that is, capable of at least a 50-millimeter stylus deflection for a volume change of 10 cubic millimeters.
5. A frequency response showing less than 3 per cent decrease in amplitude at 5 cycles.
6. A linear amplitude response with an accuracy of ±2.5 per cent to a 50-millimeter induced volume change when set at standard sensitivity.
7. Two paper speeds, 25 and 2.5 millimeters per second.
8. A rapid warm-up period.
9. Essential freedom from drift, ±1 millimeter per minute, at standard sensitivity.
10. No microphonic and a-c interference at full sensitivity.

Most of the plethysmographs previously described require some type of transducer to convert volume changes of the part under study to a graphic record. A metal capsule with a metal or rubber membrane with optical recording is used in the Wiggers' type instrument[7–10]; however, this requires photographic recording. A metal diaphragm faithfully records the waveforms, does not deteriorate, and is more practical than the rubber diaphragm.

A moving drop of fluid[4] and a water meniscus[11,12] have been photographed which give highly accurate records of volume changes and waveforms that are essentially free of distortion. However, this method offers a low range of sensitivity control and requires an hydraulic system which is difficult to manipulate.

Carbon[13] and crystal[14] microphones have been employed which measure changes in electrical resistance resulting from changes in the volume of the part. The carbon microphone allows changes in range of sensitivity with suitable amplifiers, however, severe hysteretic effects are encountered which make the base line change its position from moment to moment so that measurements of volume change cannot be recorded accurately. The crystal microphone offers a fair sensitivity with proper amplifiers and allows for changes in the range of sensitivity. It does not record faithfully, however, the slow varying pressures which are necessary for accurate plethysmography.

A capacitor has been used by Fenning and Bonar[15,16] which measures changes in electric capacitance resulting from changes in volume.

A photoelectric cell which generates a current proportional to the amount of light reaching it also has been employed.[17–22] A photoelectric transducer, operated with a metal tambour, is capable of recording volume changes and may be used with direct-writing or light beam galvanometers with ample sensitivity. However, when the photoelectric cell is used directly on the finger or toe, a record of pulsation rather than a volume change is recorded.

The electrical impedance of a region between two electrodes was measured by Nyboer.[23] This system requires the use of a high-frequency source of voltage to the electrodes over the segment of tissue being explored. Suitable amplifiers and detectors are necessary to indicate or record the changes of electrical impedance. It is elaborate in its equipment and considerable calculation is necessary to interpret the results in terms of volume change.

A heating coil and thermocouple unit has been employed.[24–26] A hot-wire thermocouple transducer does not record changes in volume of the part under study and sensitive and stable amplifiers are needed to convert the low output of the thermocouples to values suitable for direct-writing recorders.

The strain-gauge transducer[27] has been used which is usually of the unbounded-resistance-wire type and, with suitable galvanometers, may be operated without amplifiers. The strain gauge offers a faithful reproduction of the pulse waves as received from the digital pickup cup and with suitable amplifiers the range of sensitivity equals that of other electronic systems.

Capacitance transducers, which have been used also, are notorious for their complexity of operation and lack of stability.

Although widely varying instruments based on differing principles have been described, not all are suitable for plethysmography, for some do not record the volume change of the part under study. Certain instruments record pulsations in arbitrary units; thus they resemble oscillometers more closely than plethysmographs. Others record the rate of acceleration of volume changes rather than absolute changes in volume, which makes interpretation difficult. Some record volume changes in a nonlinear fashion which complicates interpretation of the results. Others lack sensitivity and are not capable of detecting the finer abnormalities of the plethysmogram and thus are not suitable for recording volume changes in small body parts, such as the digits. Still others fail to record slow volume changes, such as the alpha and beta waves, of the plethysmogram.

The electronic pneumoplethysmograph described here uses an electromechanical transducer tube, which was selected because it offers:

1. An electronic system capable of recording volume changes of the part in which flexibility of control can be obtained easily.
2. A system of direct writing.
3. A relatively high output when used in a simple circuit, a 10-cubic-millimeter volume change produces a change of 1.92 volts.

Simple photoelectric cell circuits offer relatively low output compared with the electromechanical transducer tube and the more elaborate circuits using multiplier photoelectric cells require elaborate, high-voltage, well-regulated power supplies. In comparison with the strain gauge, the electromechanical transducer tube offers a higher output and a simpler amplifier than the carrier-type amplifiers normally used with strain-gauge equipment. In addition, its operation remains trouble-free over a long period of time.

The electronic pneumoplethysmograph described has been used extensively over a period of 3 years with minimal repair. The high sensitivity of the instrument is valuable in studying waveform detail, in calculating the flow-pulsation and other ratios, and in detecting minimal disease. The compact structure of the instrument makes it suitable for multichannel recording with such instruments as the Poly-Viso recorder, so that correlations with other physiologic phenomena are possible.

CONCLUSIONS

THIS SIMPLE, direct-writing, electronic pneumoplethysmograph, employing an electromechanical transducer, is highly sensitive, portable, compact, and may be standardized accurately and adapted to such already existing galvanometers as standard electrocardiographic machines. The instrument has been tested thoroughly. It is suitable for recording systolic blood pressures at various points on the extremities, volume pulsations of the finger or toe, relative blood flow, potential blood flow, peripheral resistance, vasomotor activity, and other vascular phenomena.

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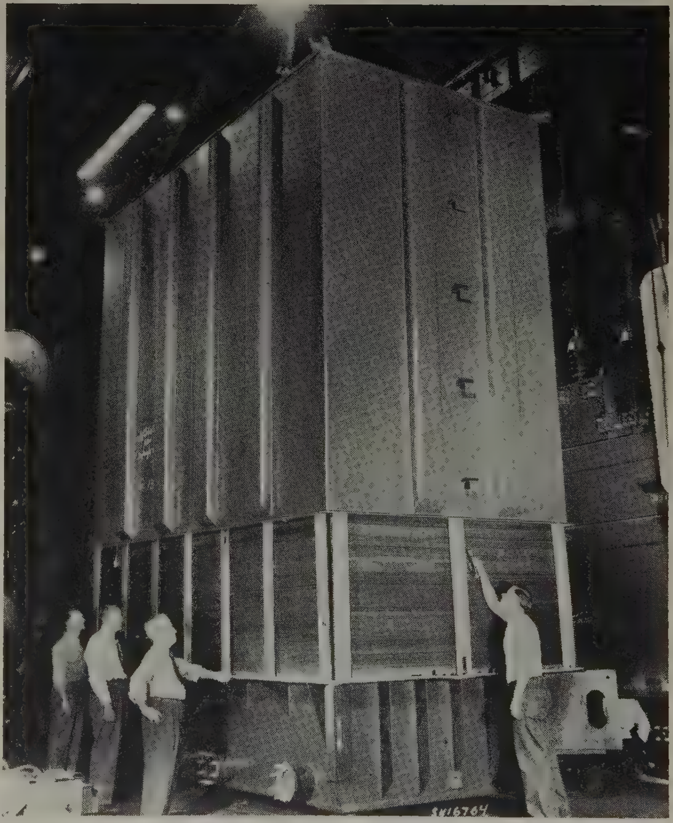
Largest Power Transformer



This 190,000-kva transformer manufactured by the Westinghouse Electric Corporation is the largest in kva capacity ever built. Shown here as its tank is being lowered into position, it weighs only 161 tons, including oil and cooling equipment, and provides oil and steel savings because of close-fitting tank

Dielectric Breakdown of Sulphur Hexafluoride

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T. W. DAKIN
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THIS ARTICLE presents some of the anomalies in the dielectric breakdown of sulphur hexafluoride as functions of pressure and electrode separation in a nonuniform field. At atmospheric pressure, this gas has unexpectedly high 60-cycle breakdown voltage for large gaps. At larger spacings, the spark-over voltage may increase more than proportional to the spacing, rather than levelling off as is more usual. This results in an inflection in the curve of breakdown voltage versus spacing, Figure 2. In this case, corona precedes spark-over.

The positive and negative d-c spark-over voltage as a function of pressure for larger gaps was investigated using several electrode configurations. A maximum was obtained in all cases in the curve of positive d-c breakdown voltage. Such maxima do not occur in gases such as pure nitrogen or helium. At higher pressure, the negative spark-over voltage is much higher than the positive.

The a-c breakdown voltage as a function of pressure for several electrode configurations and gap spacings from 1/4 inch to 2 inches was obtained. A typical set of such curves for a given electrode configuration is shown in Figure 1. These curves have closely the same shape and values nearly identical with those for positive direct current. As the electrode spacing is increased, the maximum in these curves shifts toward lower pressure, and the maximum for larger gaps is broader, encompassing the curves for smaller gaps. If a pressure in the region of the maxima in these curves is selected, for example, 3 atmospheres, and the spark-over voltage as a function of electrode spacing is plotted, the curve shown in Figure 2 is obtained.

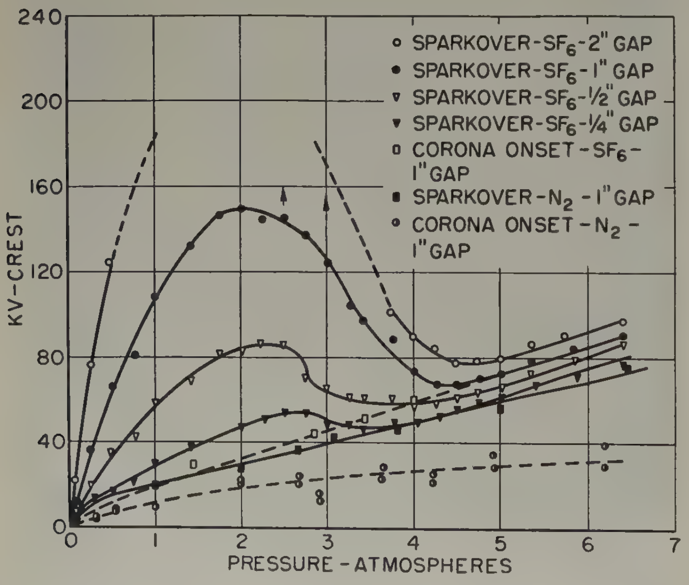

Figure 1. A-C spark-over and corona onset voltages of sulphur hexafluoride and nitrogen for indicated gaps between 1/16-inch-hemisphere point and 6-inch-diameter plane in 12-inch diameter steel tank as a function of pressure

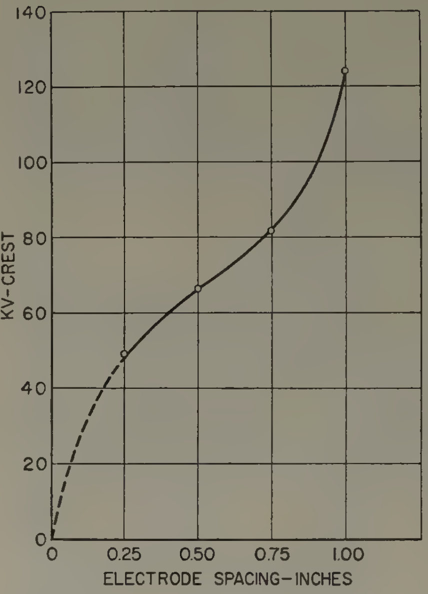

Figure 2. A-c spark-over voltage of sulphur hexafluoride as a function of electrode spacing between a 1/16-inch-hemisphere point and a 6-inch-diameter plane at 3 atmospheres pressure

The positive impulse spark-over of sulphur hexafluoride is lower than the a-c spark-over voltage except at high pressures. These data showed that the time required for the build-up of positive space charge around the sharp electrode was much less than 1 cycle, but more than a few microseconds. It is this positive space charge formed by corona which increases the d-c and low-frequency spark-over voltage by reducing the stress concentration at the sharp electrode.

Also in Figure 1, the breakdown voltage of sulphur hexafluoride is compared with that of nitrogen. Where a maximum occurs in the 60-cycle spark-over of sulphur hexafluoride, breakdown voltages of five or more times that of nitrogen may be obtained. However, such breakdown is preceded by violent corona. At the pressure of the maximum, the corona onset point in sulphur hexafluoride is of the same order as the breakdown voltage of nitrogen and about 50 per cent greater than corona onset in nitrogen. At a pressure of slightly more than 4 atmospheres, the corona onset voltage for sulphur hexafluoride is about $2^1/_2$ times that of nitrogen. With sharper points this ratio is lower. Beyond a critical pressure corona onset voltage for sulphur hexafluoride becomes coincident with breakdown. Corona onset voltage is probably more important to the designer than breakdown voltage.

Digest of paper 53-235, "Dielectric Breakdown of Sulphur Hexafluoride in Nonuniform Fields," recommended by the AIEE Committee on Basic Sciences and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 15–19, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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Analysis of Polyphase Directional Relay Torques

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AN ANALYSIS OF single-phase directional relay behavior has been made in an article entitled "A Study of Directional Element Connections for Phase Relays."[1] The scope of that article is extended here to an investigation of the 3-phase directional relay.

Relay location in the system, type of fault, and relay connection constitute the fixed considerations. Three representative relay locations are analyzed: first, the relay located between a grounded source and a length of faulted line as illustrated in Figure 1; second, the relay located between a source and a length of faulted line with the zero-sequence source concentrated at the opposite end of the line; and third, the relay located between a source and a length of faulted line, similar to Figure 1, but with a transformer bank interposed between the relay and the fault. All four types of faults are considered: line-to-line, line-to-ground, double line-to-ground, and 3-phase. Finally, the four most common relay connections are included as fixed considerations. These are usually referred to as the 90-degree, 60-degree number 1, 60-degree number 2, and 30-degree connections. The 90-degree connection is assumed to have a 45-degree shifted characteristic, while the other connections have watt characteristics.

The impedances of the system are designated as the variables for each set of fixed conditions. Both impedances behind the relay and impedances between the relay and the fault may vary in magnitude and angle.

The torque on a polyphase directional relay is the algebraic sum of the torques of the three single-phase elements. Positive torque is interpreted to mean contact-closing torque, while negative torque is contact opening. Using the concept of the dot product, the torque equation may be written

$$T_3 = V_h \cdot I_h + V_j \cdot I_j + V_k \cdot I_k \qquad (1)$$

where V_h designates the voltage applied to relay element h, I_h designates the current through relay element h, and so forth. Using symmetrical components,[2] equation 1 becomes

$$T_3 = 3|V_{h1}|\,|I_{h1}| \cos \beta_1 + 3|V_{h2}|\,|I_{h2}| \cos \beta_2 + 3|V_{h0}|\,|I_{h0}| \cos \beta_0 \qquad (2)$$

where β_1 is the angle between V_{h1} and I_{h1}, β_2 is the angle between V_{h2} and I_{h2}, and β_{h0} is the angle between V_{h0} and I_{h0}.

By evaluation of the terms of equation 2, the performance of the polyphase relay may be predicted. In this work the values of relay voltages during faults and relay currents during faults are substituted in equation 2 in terms of system impedances, and the torque thereby is defined as the sum of its three sequence component torques. The variations of the angle β are analyzed, and then all possibilities for a negative torque T_3 are noted.

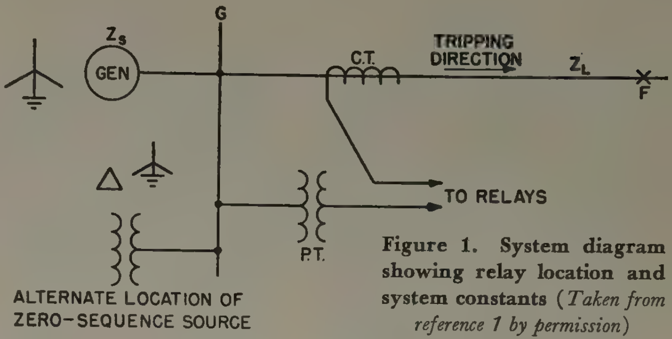

Figure 1. System diagram showing relay location and system constants (*Taken from reference 1 by permission*)

In conclusion, it may be stated that positive- and zero-sequence torques are always positive in sign and that negative-sequence torque is positive in sign except for certain faults with the 60-degree number 1, 60-degree number 2, and 30-degree connections. For a negative negative-sequence torque in these cases, the positive-sequence source impedance must be at an angle at least less than 60 degrees. Such a low source angle is very unlikely. In the extreme limiting case of zero line impedance and a positive-sequence source impedance at 0 degree, the negative-sequence torque for these particular faults and connections is just large enough to overcome the positive. The conclusion is that the shaft torque is always in the proper direction, neglecting, of course, the effect of load current.

If it is desirable to minimize the adverse effect of load current, the connection producing the maximum contact-closing torque for any given fault may be used. Neglecting resistance and evaluating the components of torque in terms of voltages and impedances, the 60-degree number 1 connection results in a total torque approximately three times that of any other connection for all three systems studied. Assigning this connection a current coil comparable in size to that used for the other connections would reduce the advantage by a factor of $\sqrt{3}$. Since this leaves a net increase in torque of $\sqrt{3}$, it would appear that the 60-degree number 1 connection best minimizes the effect of load current.

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Digest of paper **53-195**, "An Analysis of Polyphase Directional Relay Torques," recommended by the AIEE Committee on Relays and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 15–19, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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Sinusoidal Analysis of Nonlinear Control Systems

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EXTENSION OF SOME of the techniques of sinusoidal analysis familiar in linear-system theory to systems containing nonlinear elements provides much useful information concerning their design and performance. Most important is the ability to predict possible periodic behavior, both stable and unstable, of the unexcited systems. This ability allows nonlinearities to be accounted for in system synthesis so that the usually undesirable behavior implied by the periodic solutions can be prevented or at least controlled. Either linear or nonlinear correcting devices can be employed effectively for this purpose. Steady-state responses to external sinusoidal excitation, including the hysteretic frequency responses common in nonlinear systems, are determined readily when the response is of excitation frequency. The method is helpful also in obtaining a qualitative understanding of simple transient behavior.

The extension of sinusoidal analysis to nonlinear systems is accomplished through the development of special describing functions to represent the nonlinear elements. For the class of elements considered, a sinusoidal drive produces a periodic output having the same period as the driving sinusoid. The describing function of an element then is defined as the amplitude and phase angle of the fundamental component in the Fourier series representation of the response relative to the assumed driving sinusoid.

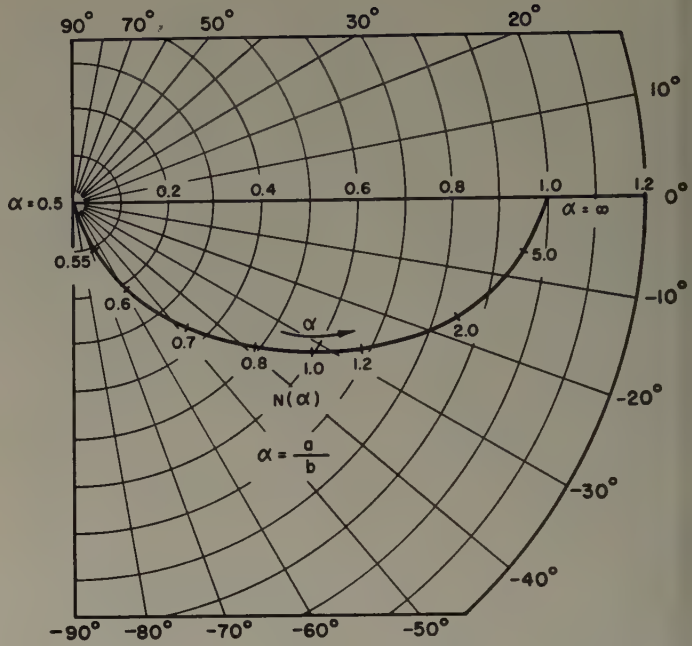

Figure 3. N(α), the free play describing function

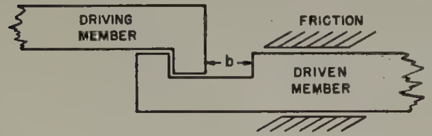

Figure 1. Simplified model for a type of backlash or free play

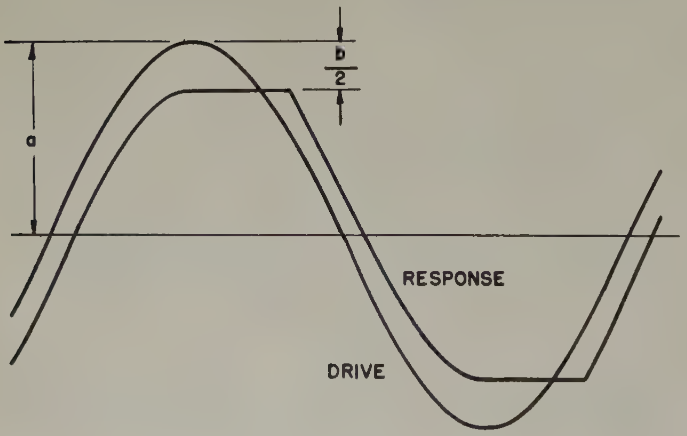

Figure 2. Waveforms of drive and response

As an example, suppose the drive linkage or gear train in a servo system contains the backlash or free play indicated schematically in Figure 1. For simplicity the inertia of the driven member is assumed negligible as compared to the friction forces acting on it. When the input or driving member is moved sinusoidally, the response of the driven member is as sketched in Figure 2. The amplitude and phase angle of the fundamental component in the response waveform may be computed in terms of the ratio of a, the amplitude of the input sinusoid, to b, the amount of free play. Let α be this nondimensional amplitude ratio. The describing function, $N(\alpha)$, now, is the complex amplitude of the output fundamental relative to a. Figure 3 shows a sketch of $N(\alpha)$ as a locus in the complex plane.

Describing functions are analogous to the usual steady-state transfer functions of linear elements, but in general they depend upon the amplitude of the driving sinusoid as well as the frequency. For the purpose of investigating system behavior, describing functions for the nonlinear elements are combined with transfer functions for the linear elements. The locus techniques of conventional servo theory provide convenient means for carrying out such studies in the case of single-loop or single-nonlinearity systems.

The use of describing functions in this way completely disregards the higher harmonics generated by the nonlinear elements. Nevertheless, the results so obtained are accurate to within 5 to 10 per cent for a wide variety of systems. Higher order approximations have been developed from which greater accuracy can be obtained if desired.

Digest of paper 52-154, "Sinusoidal Analysis of Feedback Control Systems Containing Nonlinear Elements," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Minneapolis, Minn., June 23–27, 1952. Published in AIEE *Transactions*, volume 71, part II, 1952, pages 169–81.

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Fast-Response High-Current Thyratron Power Supplies for Inductive Loads

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With the increasing importance of reducing the response time of inductive loads, the power capabilities of modern high-current gas thyratron tubes become very significant. As amplifiers these tubes introduce no appreciable additional time constant into the system. Several methods for energizing loads such as fields of large motor generators, solenoids, magnetic clutches, and electromagnets are discussed including the half-wave circuit with an optimum value of capacitance in parallel with the load. This method provides the fastest response for the equipment required.

FREQUENTLY in industrial regulators or servomechanisms it is desirable to vary the current in an inductive load with rapid response to avoid hunting, or to improve control accuracy. As the power requirement of large electric equipment increases, the inherent natural time constant tends to become long. Therefore, various means of reducing the response time of loads such as fields of large motor generators, solenoids, magnetic clutches, electromagnets, and others, may be very significant. Such loads fall within the power capabilities of modern high-current gas thyratron tubes, which as amplifiers introduce no appreciable additional time constant in the system.

A traditional method for energizing such loads has been the half-wave circuit with back rectifier shown in Figure 1. The thyratron grid voltage determines at what instant in the anode positive half-cycle the tube will conduct. Current flow through this tube continues until the line voltage reverses, at which time the voltage generated by the decaying current in the load inductance causes the rectifier connected across the load to conduct, and a decreasing load current continues to flow through this tube until the thyratron again is fired on the next positive anode half-cycle. Figure 2 shows typical transient response for this circuit, where the load consists of 2.0 henrys and 30.0 ohms, which might be typical of the field of a 15-kw d-c generator. Improvement of response speed on start, or when grid signal voltage calls for more output, may be obtained by the use of a higher a-c supply voltage, as a forcing voltage. The required d-c output voltage may then be maintained by delaying the grid firing angle sufficiently for the desired steady state.

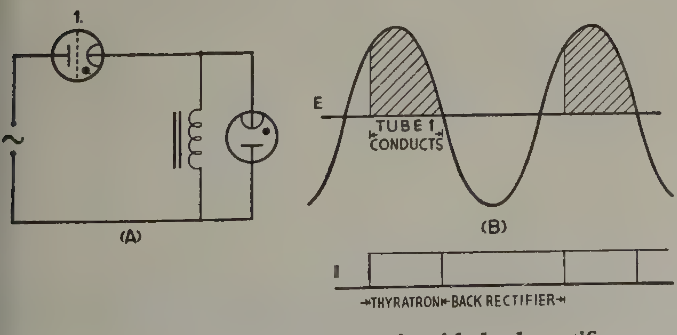

Figure 1. Half-wave thyratron circuit with back rectifier connected across inductive load

A faster method, which has been described for industrial inductive load applications, is the full-wave thyratron circuit, where the decrease of load current is speeded up by operating in the inverter mode. The typical circuit arrangement and the anode voltage waveforms for continuous current in the load are shown in Figure 3. As long as there is a source of voltage in the load, if the firing angle is delayed more than 90 degrees, the circuit inverts the energy stored in the load inductance and transfers it back to the a-c line. The variation in direct voltage with grid retard angle for this circuit is shown in Figure 4. If the firing angle as a rectifier is θ_1 and as an inverter θ_2, for most practical values of the angles, the load current will be forced to its discontinuous value in the electrical time constant of the load times $\cos\theta_1/(\cos\theta_1-\cos\theta_2)$, neglecting tube and transformer losses.

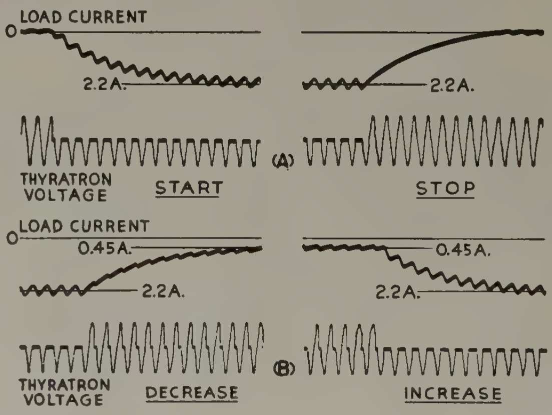

Figure 2. Transient changes in load current half-wave circuit with back rectifier: *L=2 henrys; R=30 ohms*

A new method, which offers the fastest response for the

Revised text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953, and recommended for publication by the AIEE Committee on Electronics.

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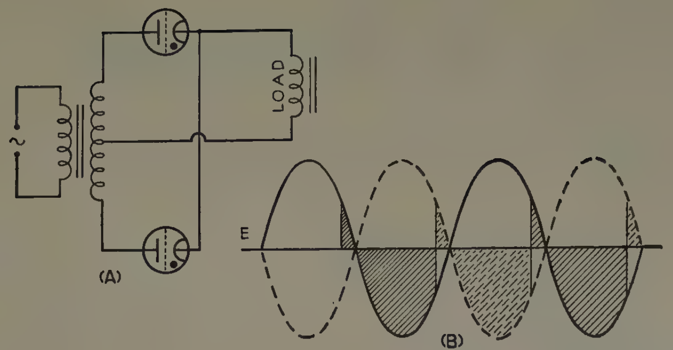

Figure 3. Full-wave rectifier with inductive load. Firing delayed to 160 degrees for inversion of the stored energy from the inductive load

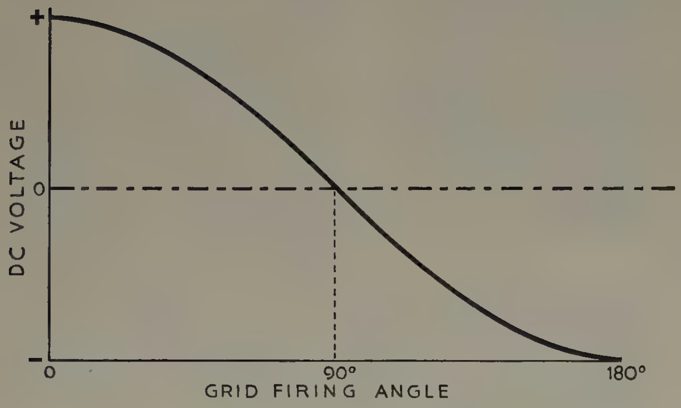

Figure 4. Relation of grid firing angle to direct voltage in full-wave thyratron circuit with inductive load showing inverter action between 90 and 180 degrees

equipment required, is the half-wave circuit with an optimum value of capacitance in parallel with the load. Such an arrangement with typical parameters for reversing control is shown in Figure 5, with two thyratrons connected in inverse parallel. The oscillograph peak current rating of the tubes and the line voltage, set the value of the resistance, *r*. The shunt capacitor serves a double purpose. It provides a means for continuous current in the load with half-wave rectification; and secondly, it provides, at the desired time, a forcing voltage to vary the load current as required.

Since the capacitor will charge up to nearly the peak of the a-c line voltage each cycle (or higher if there is inductance in the supply) unless limited from doing so by delayed grid firing of the thyratron, this voltage is available during the tubes' nonconducting half-cycle to support load current. Upon decreasing signal, or reversing signal, the stored energy of the load inductance is transferred to stored energy in the capacitor. Since the stored energy in the inductance at full load current is larger than that which is stored in the capacitor in any one cycle of the line voltage, the capacitor overcharges with reversed polarity to absorb this energy. The overvoltage is then available to force the build-up of reversed current in the load. Figure 6*A* shows, for various values of load current, the relationship of the ratio of load inductance/shunt capacitance to the forcing voltage which occurs on sudden reversing signal, if all of the energy of th inductance is transferred to the capacitance and th I^2R losses as well as the energy stored in the capacitor whe reversal begins are neglected. This figure is a graph of th equation:

$$\frac{LI^2}{2}=\frac{CE^2}{2}$$

where

L=Load inductance
I=D-c load current
C=Shunt capacitance
E=Maximum forcing voltage

Laboratory measurements on several loads with variou capacitors and load currents check this quite closely if th effect of load current ripple and the foregoing assumption are considered. By proper choice of the circuit parameters, it therefore is possible to obtain transient forcing voltages over a wide range. Choice of capacito size is also influenced by the available a-c line voltage tube peak forward voltage rating, and desired d-c outpu voltage. Figure 6*B* shows the capacitor size with variou load inductances and load currents, for a maximum forcing voltage of 1,000 volts, on the basis of data plotted from Figure 6*A*. Figure 7 shows the relationship of the capacitor size and the ratio of alternating to direct voltage for two specific inductive loads. Approximate design values for a desired d-c output can be calculated by a step-by-step analysis using small increments of time. I is surprising how accurate such a calculation proves to be, even with the use of 10-degree increments.

The transient response of the 2-henry 30-ohm load with half-wave thyratron supply and a shunt capacitance of 40 microfarads is shown in Figures 8 and 9. The d-c output voltage, with the *C3J/A* thyratron firing full was 65 volts. This is the same load, and the same direc voltage as existed in the half-wave circuit with back rectifier described in Figure 1 and Figure 2, so their responses may be directly compared. The resistor *r* of 12.5 ohms limits the peak current through the thyratron to within its 30-ampere maximum rating. As with other capacitor load circuits, the tube peak current may be limited alternatively by a small inductance in the supply

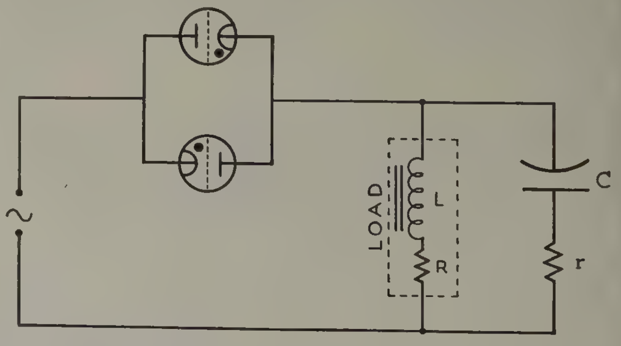

Figure 5. Half-wave thyratron supply to an inductive load with shunt capacitor for fast reversing of load current. Parameters for specific circuit analyzed: *L=2 henrys; R=30 ohms; C=40 microfarads; r=12.5 ohms*

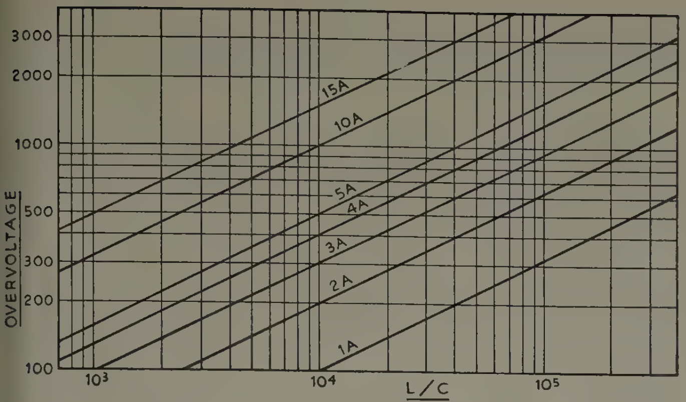

Figure 6A. Maximum forcing voltage during current reversal in inductance L with shunt capacitor C for half-wave thyratron supply circuit (I^2R losses assumed zero)

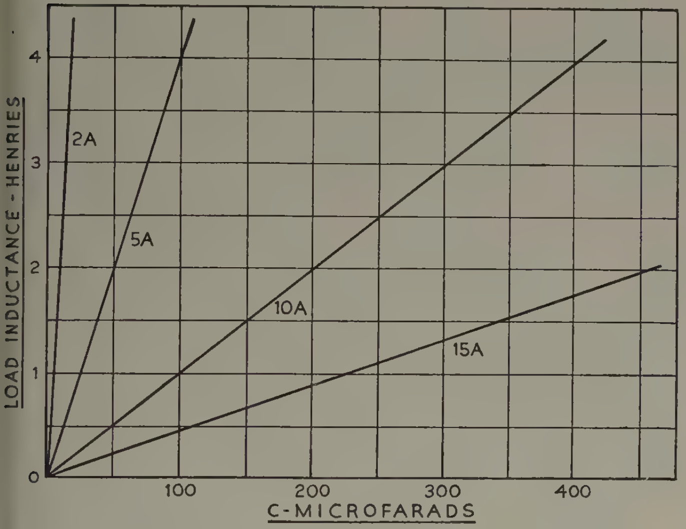

Figure 6B. Shunt capacitance for 1,000-volt forcing voltage in relation to load inductance at various load currents

line. It is interesting to note, however, that the presence of some line inductance may permit the capacitor to charge up to a voltage greater than the peak a-c line voltage each cycle, and actually results in a higher d-c output voltage than without line inductance. For example, in the circuit of Figure 5, connection of a 30-millihenry choke in the a-c supply line raises the steady-state peak capacitor voltage 5 per cent, and the direct voltage 8 per cent.

There are several points to note especially on these oscillograms. The load has a natural time constant of 1/15 second, or 4 cycles of the 60-cycle line voltage. However, after reversing signal and the end of conduction of the forward tube, the load current reaches zero in less than 0.7 cycle, or 18 per cent of the time constant of the load, and has reached 93 per cent of the final value in the opposite direction 1.3 cycles later, or the total excursion in 50 per cent of the time constant of the load.

The anode to cathode voltage which is shown, indicates the tubes' peak forward and peak inverse voltage duty. During the transients, the load forcing voltage is the difference between the tube voltage and the line voltage, and so may be determined easily.

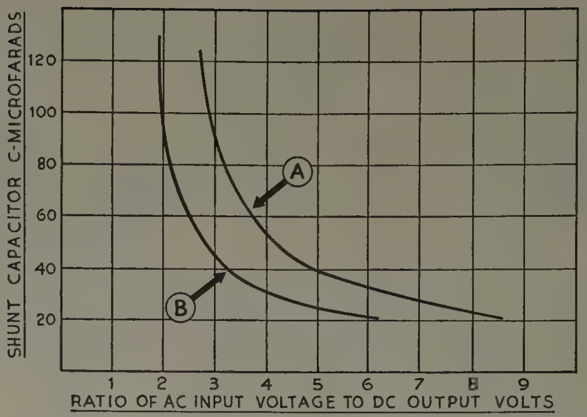

Figure 7. Effect of shunt capacitor size on ratio of alternating input voltage to direct output voltage in half-wave rectifier circuit with inductive load. *A Load: L=0.8 henry; R=29.5 ohms; B Load: L=2 henrys; R=30 ohms*

It is interesting to note on Figure 8*A* that following the change in grid signal voltage the conducting tube ceases conduction, and the reversing tube conducts one-half cycle discharging the capacitor through the line. The discharged capacitor is then available to absorb the charge of opposite polarity as the stored energy of the inductance is transferred to it. The oscillogram also shows that the reversed voltage on the capacitor has risen sufficiently within the first cycle to prevent conduction of the reversing tube on the succeeding cycle. Thus the capacitor promptly absorbs the stored energy of the load at a transient overvoltage, which then becomes the forcing voltage during the first cycle after the reversing signal occurs.

In Figure 9, the transient changes in load current are the result of a step change in the grid firing angle. In a closed-cycle system further improvement in transient decrease could be obtained, since the thyratron grid would prevent tube conduction until the output dropped to the desired level.

The oscillatory decay present when the grid prevents all further conduction as shown in Figure 8*B*, occurs at the

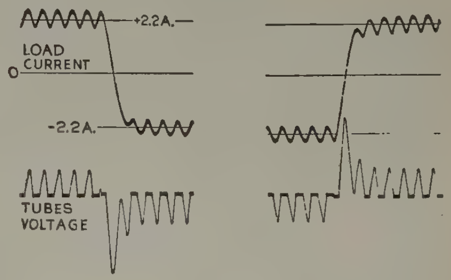

Figure 8A. Sudden current reversal in inductive load supplied by half-wave thyratron circuit with shunt capacitor, showing transient forcing voltage. *L=2 henrys; R=30 ohms; C=40 microfarads*

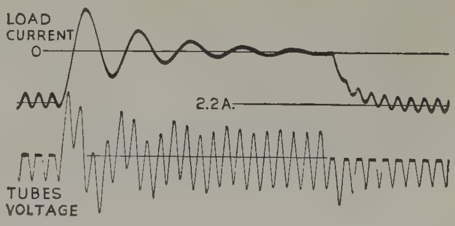

Figure 8B. Decay and rise of current in an inductive load supplied by half-wave thyratron circuit with shunt capacitor. *L, R, and C, as in 8A.*

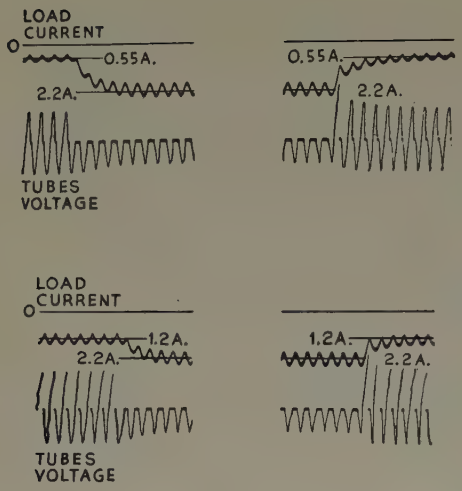

Figure 9. Transient changes in load current, half-wave circuit with shunt capacitor. *L=2 henrys; R=30 ohms; C=40 microfarads*

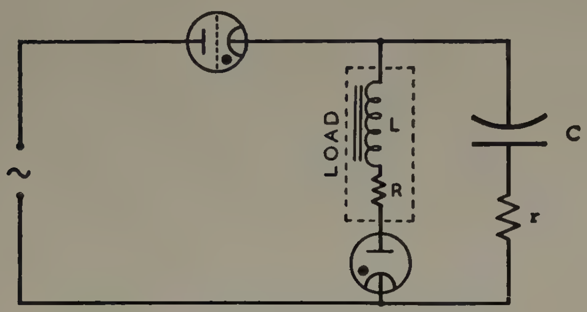

Figure 10. Half-wave thyratron supply with shunt capacitor for fast energizing and de-energizing of inductive load. *L=2 henrys; R=30 ohms; C=40 microfarads; r=12.5 ohms*

natural frequency determined approximately by $1/2\pi\sqrt{LC}$, or 18 cycles in the case shown. If it is not desired to reverse the current in the load, this oscillatory decay to zero may be eliminated by connecting a diode in series with the load to prevent reverse current flow as shown in Figure 10. For the 2-henry 30-ohm load the current then reaches zero in approximately one cycle, or 0.25 of the time constant of the load, after the signal voltage prevents further thyratron conduction. The inductive energy is transferred to the capacitor which remains charged until discharged through the line on the first conduction cycle of the thyratron when next fired.

If "back-to-back" thyratron and diode are connected in place of the diode shown in Figure 10, it is possible, if desired, to provide for a half-cycle oscillation of demagnetizing current to flow in the load immediately following the "turn-off" signal.

One application of the half-wave circuit with shunt capacitance reverses a 12-ampere field of a 70-kw d-c generator with a pair of *C16J* tubes, more than ten times faster than with normal voltage switching. Table I shows a comparison of the approximate typical responses of inductive loads supplied by the three methods discussed, in terms of the natural time constant of the load.

Table I. Approximate Comparable Response Times

Function	In T* Times	A§ D-C Supply	B‖ Back Rectifier	C¶ Full Wave With Inversion	D** Half Wave With Shunt Capacitance (Instantaneous current values)
Start	0.95 FLC†	3.0	2.5	2.1	0.6
Stop	0.05 FLC	3.0	3.0	0.41	0.24
Reverse	0.93 FLRC‡	6.0	5.5	2.5	0.5

* T=Natural time constant of load.

† FLC=Full load current.

‡ FLRC=Full load reverse current.

§ Switch at 5-per-cent current.

‖ Fired at 45 degrees steady state. Switch at 5-per-cent current.

¶ Fired at 45 degrees as a rectifier, steady state, and 160 degrees as an inverter. Switch at 5-per-cent current.

** L/C as in Figure 5. Full fired.

Large New Magnetizing Unit Used on Radio Assembly Line

A $2^1/_2$-ton magnetizing unit has been placed in operation in the loudspeaker assembly line of the Stromberg-Carlson Company. This new electromagnet was designed especially for magnetizing the permanent magnet in the company's 15-inch high-fidelity loudspeaker. It also serves in magnetizing smaller units.

The magnetizing unit consists of a steel yoke, supporting the two pole pieces, each 1 foot in diameter. Each of the pole pieces is wound with three coils, and each coil contains 1,450 turns of number 12 cotton-enamel copper wire. There are approximately 700 pounds of copper in the coils. The complete assembly weighs slightly over 5,000 pounds and requires special supports.

The electromagnet is activated by a self-excited generator which supplies 50 amperes at 300 volts to the coils. The density of the magnetic flux in the unit's air gap is 10,000 gauss. However, when one of the 15-inch speakers is introduced into the gap, the flux density rises to 14,000 gauss. An even further concentration of the magnetic flux occurs after the speaker is removed from the electromagnet's field. At the high-frequency end of the magnet, the flux density then becomes about 15,000 gauss.

Magnetizing of the speakers' permanent magnets is one of the final steps in the assembly line, and the speakers are virtually complete. A slow-moving endless belt, which glides directly over the face of the magnet's lower pole, carries the loudspeakers through the magnetic flux. Activation of the electromagnet's coils is controlled by a photoelectric relay device. The electric eye is so placed that a loudspeaker passing through the magnet's gap interrupts the beam of light as the speaker approaches the center of the gap. That switches current into the coils. A time switch, which can be adjusted to different intervals, cuts the power off.

Physical Concepts of Corona in Capacitors

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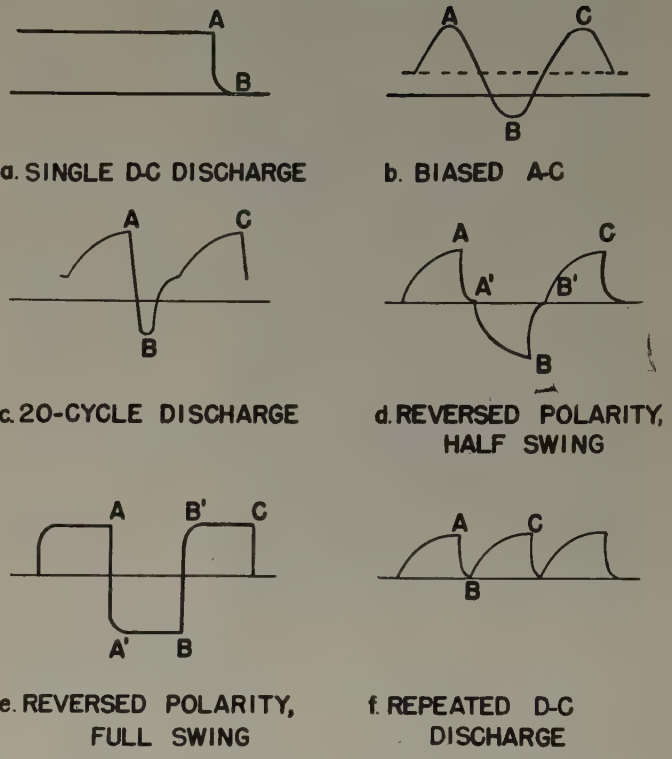
CORONA OFTEN BECOMES the limiting factor in determining satisfactory voltage stress levels in capacitors where high operating stresses are desirable, and obtainable through the use of high-quality insulation. Recognition of this factor has resulted in extensive investigations[1] of the effects on corona of many design and operating variables, and subsequent analysis of test results has revealed certain concepts which explain much of the behavior of corona in thin dielectrics.

In liquid-impregnated capacitor dielectrics, corona is largely a surface creepage phenomenon. The behavior of corona, therefore, is determined to a great extent by the surface conductance of the dielectric, shown as R_s in the equivalent circuit of the dielectric, Figure 1. For example, on direct voltage, corona does not occur because the capacitances C_p are charged by conduction and very small voltage gradients exist along the paper surface in the vicinity of the foil edge. However, if direct voltage is quickly applied to or removed from the capacitor, corona does occur because the potential of the capacitances C_p cannot follow the rapid voltage changes. A high-voltage gradient therefore appears at the foil edge and discharge in the liquid impregnant results.

When cyclic voltages are applied to liquid-impregnated capacitors, several types of corona appear, differing in magnitude and in phase relation to the applied voltage. The most important of these types is termed sustained corona, the pulses of which appear over a large portion of the various waveshapes shown in Figure 2, and from about voltage zero to the following voltage peak on sinusoidal waves. The appearance of this corona is due to a voltage gradient established by space charge which has been created on previous cycles, and which has not had sufficient time to move away from the foil edge by conduction. Most important, the appearance of sustained corona depends only upon the total swing in voltage (peak to peak) and the "relaxation time." This is the time from B to C (Figure 2). The longer the relaxation time, the higher the corona-starting voltage becomes.

In "perfect" dry capacitor dielectrics with nearly infinite leakage resistance R_s, corona behaves quite differently. For example, corona occurs initially in a given capacitor at the same applied voltage regardless of the frequency or waveshape (based on tests up to 500,000 cycles per second). However, the initial corona persists only long enough to reduce, by the action of space charge, the gradient at the foil edge to a critical value. On cyclic waves, whether sinusoidal in shape or complex such as those waves in Figure 2, steady corona occurs on both voltage peaks at an applied voltage swing equal to twice the initial corona starting voltage.



a. SINGLE D-C DISCHARGE b. BIASED A-C
c. 20-CYCLE DISCHARGE d. REVERSED POLARITY, HALF SWING
e. REVERSED POLARITY, FULL SWING f. REPEATED D-C DISCHARGE

Figure 2. Voltage waveshapes on which corona characteristics have been studied

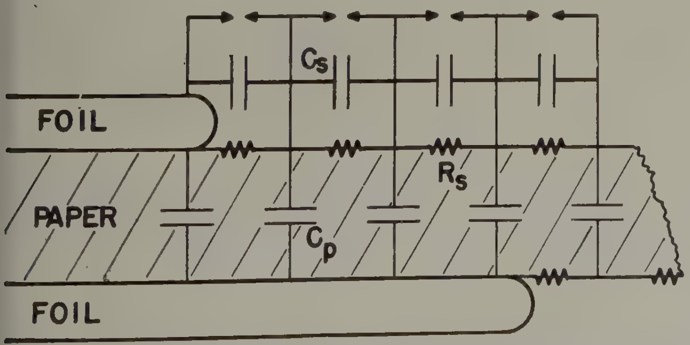


Figure 1. Equivalent circuit of a capacitor dielectric. C_s and R_s = distributed capacitance and resistance along the surface of the paper; C_p = distributed capacitance through the paper; the gaps represent the dielectric momentarily made highly conducting by the corona

REFERENCE

1. Development of Corona Measurements and Their Relation to the Dielectric Strength of Capacitors, **R. J. Hopkins, T. R. Walters, M. E. Scoville.** AIEE *Transactions*, volume 70, part II, 1951, pages 1643–51.

Digest of paper 53-229, "Physical Concepts of Corona in Capacitors," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 15–19, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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Life of Oil-Immersed Insulation Structures

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SINCE THERMAL DETERIORATION, commonly called aging, is recognized generally as the predominant factor in determining life expectancy of oil-immersed insulation structures, its effect on samples of various materials has been the subject of extensive research.[1, 2] In using these experimental data to determine the effect of loading on apparatus life, it is convenient to define the "aging factor" at a given temperature as the ratio of the corresponding rate of deterioration to the rate at some reference temperature, as in Figure 1. For a varying temperature cycle, the integral of a plot of the corresponding aging factors, as in Figure 2, gives the "equivalent aging time," or the time required, at the reference temperature, to produce the same aging. The cumulative effect of several cycles may be obtained by adding the equivalent aging times at a common reference temperature.

While these techniques permit calculation of the relative aging effects of various loading schedules, determination of apparatus life expectancy requires a definition of the end point of useful life. If we define it as the stage of deterioration at which the apparatus fails to pass a specified test routine, we may determine life expectancy in terms of equivalent operation at the reference temperature by moderately short-duration tests to failure, and the techniques previously described.

It may be easier to interpret such test results if the resultant aging is expressed in terms of temperature, rather than time.

For example, eight small distribution transformers were given overload cycles producing aging equivalent to 20 years' operation at hotspot temperatures ranging from 107 to 183 degrees centigrade. No failures occurred on subsequent American Standards Association (ASA) standard insulation tests for new transformers, where the equivalent sustained aging temperature was 122 degrees or less. At higher temperatures, failures occurred on progressively less severe insulation tests.

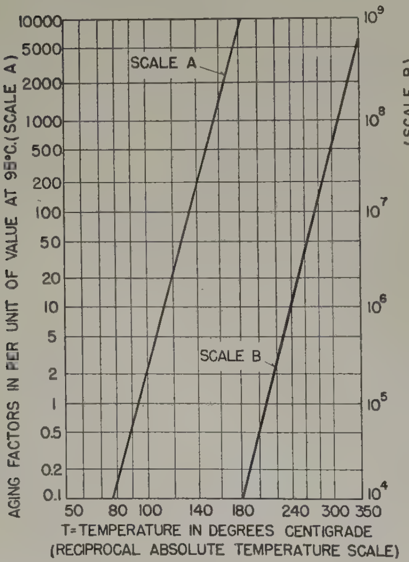

Figure 1. Aging factors for tensile strength of manila paper in oil, by chemical rate rule

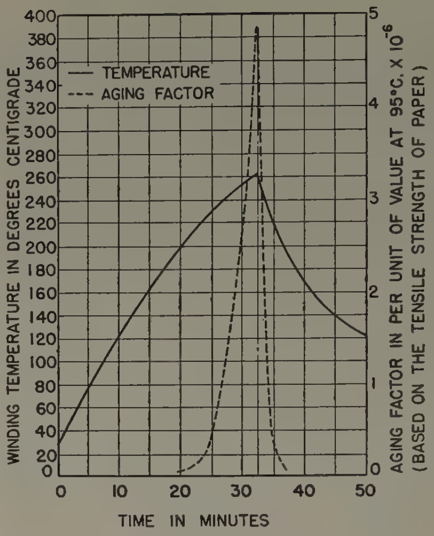

Figure 2. Hot-spot temperature and corresponding aging transients, from test of a small distribution transformer

Hence, assuming that the standard insulation tests are a suitable measure of the end point of useful life, we have some indication that these insulation structures have a life expectancy of about 20 years, at loadings with equivalent sustained aging temperature of 122 degrees. This is about 100 times the expectancy indicated by the ASA Guide for Loading Oil-Immersed Distribution and Power Transformers (*C57.32*). Part of this difference in life expectancy is attributable to the necessary conservatism of the Guide for Loading, and part may result from assumptions made, especially in using tensile strength as a measure of transformer life. While it implies that the Guide may be unduly conservative, additional research is indicated before a revision would be justified. This research should result in the establishment of aging-factor curves for commonly used insulating materials and an acceptable end-point test for apparatus. The procedures described then will permit the determination, with considerable confidence, of the normal life expectancy of a given structure on a given loading schedule.

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2. Electrical Insulation Deterioration Treated as a Chemical Rate Phenomenon, **T. W. Dakin.** AIEE *Transactions*, volume 67, 1948, pages 113–22.

Digest of paper 53-243, "Life Expectancy of Oil-Immersed Insulation Structures," recommended by the AIEE Committee on Transformers and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 15–19, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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A New Compressed-Air Circuit Breaker

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THE COMPRESSED-AIR circuit breaker for arc-furnace switching has become a firm component of the compressed-air circuit breaker line. Since 1947 when compressed-air arc-furnace breakers were introduced, 30 have been installed and several since then have been operated nearly 100,000 times each. Developments and redesign of the powerhouse breakers gained from the past 14 years of service have been combined with the experience obtained on the arc-furnace breakers to date and a new design of compressed-air arc-furnace breaker has resulted.

Statistically, the part of this history relating to arc-furnace breakers has shown an average duty for this service may be as high as 2,049 breaker operations per month. This was taken from logged data of 59,331 and 51,124 operations, respectively, on two breakers over a 27-month period. Generally equally severe service has been indicated for several of the other 30-odd breakers now in service, but long-time data are not available. Although the history of the arc-furnace compressed-air circuit breaker has shown successful service, its earlier design did not incorporate primary short-circuit interrupting ability, being limited to overload interruptions of less than 3,000 amperes. Thus a backup breaker for heavy short circuits was required and its cost, in some cases, made the compressed-air arc-furnace breaker uneconomical. Another factor influencing the redesign of this breaker was the redesign of the standard powerhouse breaker. The economies of a standard line of breakers were evident and the availability of spare parts for the furnace breaker that are common with those of the high-activity powerhouse breaker would permit shorter delivery and better service to the arc-furnace breaker user.

Accordingly, the furnace breaker was redesigned using the standard powerhouse breaker as a base. Only those alterations were made as dictated by design limits, mechanical life tests, previous field experience, and those required for arc-furnace switching. The new breaker has been designed for ratings of 14.4 kv and 34.5 kv with interrupting capacity for 500,000 kva. A front view of a 34.5-kv breaker is shown in Figure 1, complete with surge suppressors retained from the earlier design of these circuit breakers.

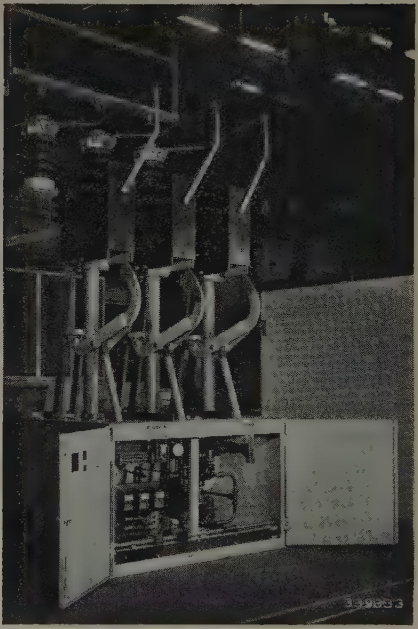

Figure 1. A 34.5-kv compressed-air circuit breaker for arc-furnace switching

This breaker, as redesigned, was subjected to a preliminary life test of 5,000 operations without current interruption, then with a life test of 10,000 operations switching load currents common to arc furnaces. The circuit was loaded by reactors through transformers to simulate currents and transient voltages produced in arc-furnace circuits. Throughout these two series of tests, maintenance consisted of renewing the contact lubricant after each group of approximately 2,000 operations and checking for loose cotter pins after each 600 operations. Shear of standard cotter pins was the only deficiency noted. This was corrected by substituting heat-treated and case-hardened knee-hump cotter pins.

Without modification to breaker parts other than the cotter pins, interrupting tests were made to demonstrate short-circuit interrupting capacity at working pressures common to plant air lines (65 to 100 pounds per square inch). Successful interruptions were obtained at 100, 75, and 65 pounds per square inch at test voltages of 13.2, 22, and 33 kv in excess of 500,000 kva at each voltage and pressure. The ability of this breaker to close into circuits capable of producing a 500,000-kva short circuit and to carry the corresponding momentary current was demonstrated by making close-opening tests at the three test pressures. The same set of contacts and arc chutes were used on both the life testing and the interrupting tests.

Since sufficient life testing had not been made to verify the use of the heat-treated knee-hump cotter pins, an additional 12,000 operations were made on the breaker with no detectable wear on the knee-hump cotter pins. Thus operations in excess of 27,000 operations were made on the breaker mechanical parts without breakdown.

The tests made on this circuit breaker have shown its capacity to interrupt, at shop air-line pressures, arc-furnace switching currents without producing transient overvoltages on the circuit. The number of repeated breaker operations during test has shown the adequacy of the breaker for highly repetitive arc-furnace switching and is in considerable excess of the National Electrical Manufacturers Association Standard of 15,000 operations without major maintenance.

Digest of paper 53-234, "A New Compressed-Air Circuit Breaker for Arc-Furnace Switching Duty," recommended by the AIEE Committee on Switchgear and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 15–19, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

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Oil-Immersed 110-Kv 440-Kw Rectifier Unit

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THE PROTON LINEAR ACCELERATOR installation at the University of Minnesota requires as one of its power supplies a d-c source capable of delivering continuously 4 amperes at 110 kv. This power represents the plate supply for four resnatron tubes which provide the radio-frequency power to excite the resonant cavities of the accelerator proper. The design of a power supply capable of meeting these requirements was complicated by the limited amount of available space.

In order to conserve floor space a vault was built extending 9 feet below the floor level, a metal liner was provided, the vault filled with 3,500 gallons of transformer oil, and the rectifier components placed in it. This not only conserved space but was justified economically since all the transformers could be uncased and used without bushings. A 1-line diagram of the components involved in the power supply is shown in Figure 1.

The electric connections in the vault are made in such a manner as to allow individual removal of any one of the rectifier or filament transformers. The rectifier transformers are connected delta-delta with the deltas closed on the primary and secondary bus structures. Flexible leads and plug-type connectors allow the transformers to be disconnected from the busses and readily removed. Lowering and raising guides are provided to insure proper seating of each transformer unit as may be seen in Figure 2.

The choice of a 3-phase full-wave bridge as the rectifier circuit required that there be six rectifier tubes, each having a peak inverse voltage rating of at least 130,000 volts, a peak current rating well above 4 amperes, and an average current rating of at least 1.3 amperes. No single kenotron was found which would meet these requirements so that series and parallel combinations of available tubes were considered. The final choice was the *ML-5576/200* kenotron, rated at 150,000 volts peak inverse, 2.5 amperes peak current, and 0.8 ampere average current, with two tubes in parallel at each rectifier position. The tubes were tested and paired according to their conductivity so as to insure a proper load division. If the filament of one tube of a pair should burn out, relays will remove plate power from the system.

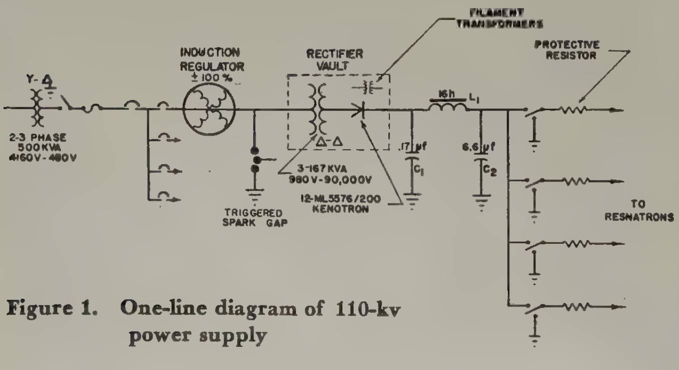

Figure 1. One-line diagram of 110-kv power supply

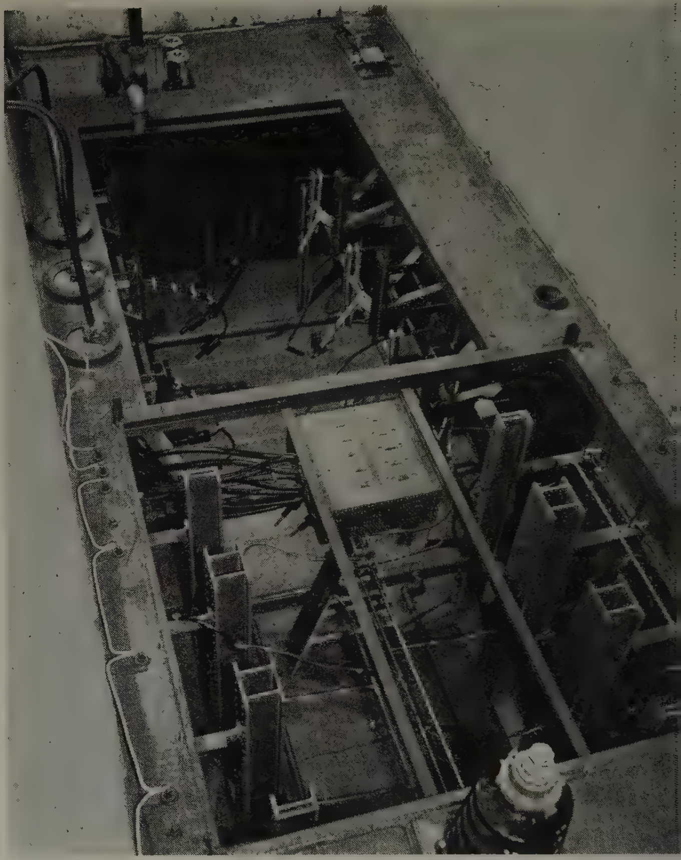

Figure 2. Rectifier vault prior to transformer installation

Special features of this installation include the use of a low-voltage spark gap which places a short circuit on the rectifier input when a fault develops. This reduces the a-c power input to a level which is safe for the kenotrons during the circuit-breaker clearing time.

It is the opinion of the authors that a rectifier such as described in this article is somewhat unique in its field. Many high-voltage supplies have been built but very few with a relatively high current rating.

Preliminary testing of this rectifier has indicated that the design is basically sound and there have been no troubles to date with the standard equipment used. Little difficulty has been experienced with the items developed specifically for this application. Future testing may result in minor alterations of the components, but no basic changes in the over-all design are contemplated.

Digest of paper 53-67, "Oil-Immersed 110-Kv 440-Kw Rectifier Unit for Resnatron Plat Supply," recommended by the AIEE Committee on Electronic Power Converters an approved by the AIEE Committee on Technical Operations for presentation at th AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953. Schedule for publication in AIEE *Transactions*, volume 72, 1953.

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The authors wish to acknowledge the valuable assistance o Edward A. Day, Researc Associate, University of Minnesota.

Antiswing Crane With Anticreep Variable-Speed Hoisting

R. C. GOERTZ

When a crane is carrying radioactive, thermally hot, or other hazardous materials, it is dangerous for riggers to prevent the load from swaying. Servomechanism feedback techniques have been applied to the carriage drive to stop the swinging and to the hoist drive to obtain variable-speed hoisting.

BRIDGE CRANES equipped with cables and a hook generally are driven in the horizontal directions and in hoisting by the use of switch-controlled electric motors. This arrangement allows the load to swing as a pendulum whenever the crane is started or stopped and the hoisting is often stopped or started rather abruptly. In many cases the characteristics of these controls have no adverse effect on the performance of the crane. However, when the crane is carrying radioactive, thermally hot, or other hazardous materials that prevent riggers from steadying the hook, it is desirable to move the load in the horizontal and vertical directions smoothly and without swinging.

Servomechanism feedback techniques have been applied to the carriage drive to stop the swinging and to the hoist drive to obtain continuously variable speed hoisting with an automatic smooth stopping feature. These two arrangements have been tried on a laboratory model crane which has attracted considerable interest. The antiswing control and the anticreep variable-speed hoisting drive are two separate control systems and are independent in their actions. The two systems will be described separately.

ANTISWING CRANE SYSTEM

IT IS WELL KNOWN that a load attached to the cables of a bridge crane will be set into a swinging motion whenever the crane is started or stopped. A skilled crane operator can reduce the amount of swinging by judiciously maneuvering the crane carriage. He has difficulty, however, in spotting the crane to the exact location and at the same time completely stopping the swinging action. Very often riggers are required to steady the load.

By utilizing some of the well-known servomechanism techniques it is possible to direct the crane to any desired position, have it go to that position keeping the swing of the load small, and then automatically reduce the swing to zero as the selected position is reached. These conditions are achieved by replacing the ordinary bridge drive motors with servo systems.

Figure 1 schematically illustrates the physical and electrical arrangement of the model. The carriage drive consists of a positional servomechanism having high viscous damping. An additional signal, θ_s, is added at the conventional summation point just ahead of the servo amplifier. This signal is proportional to the angle the cable makes with the vertical. If the constants of this system are correctly adjusted, a swing set into the load is quickly attenuated. The experimental model uses an amplidyne generator and

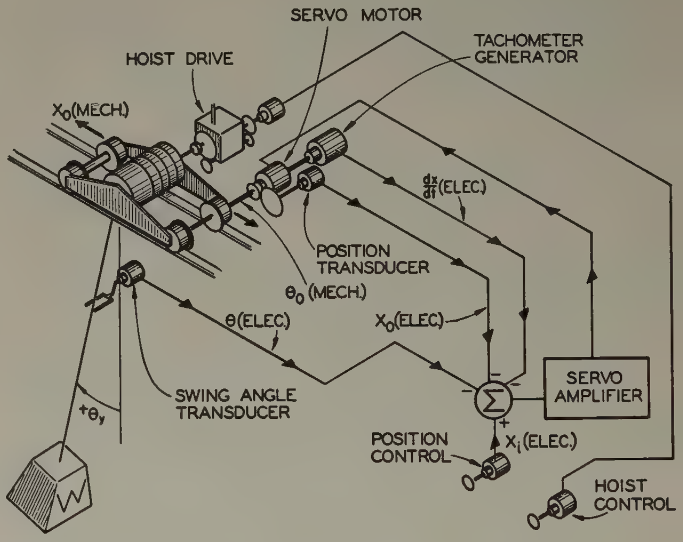

Figure 1. Schematic diagram of the physical and electrical arrangement of the model antiswing crane

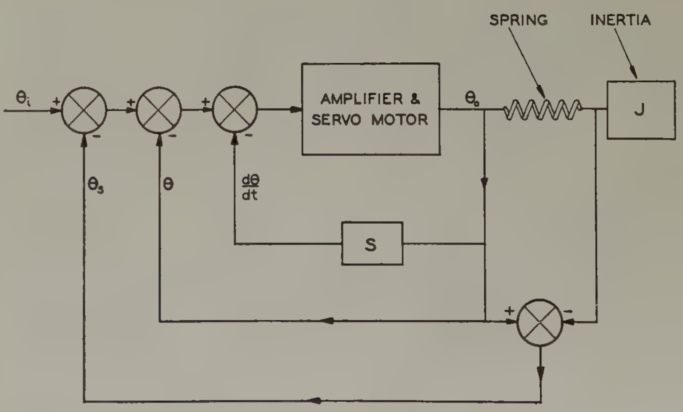

Figure 2. Block diagram of the antiswing crane servo system where the load has rotating inertia

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Special article recommended for publication by the AIEE Committee on Feedback Control Systems.

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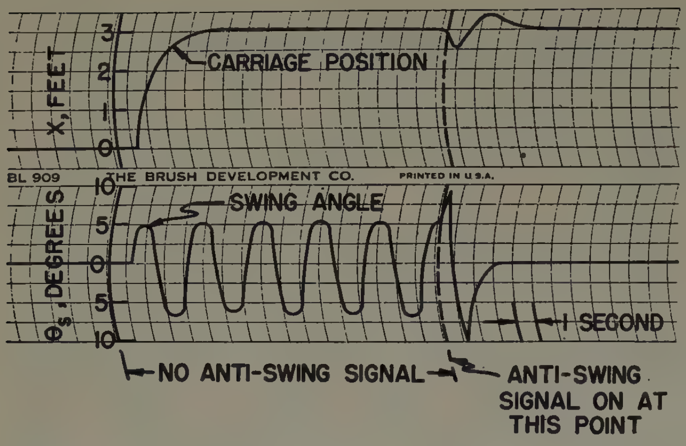


Figure 3. Record of the antiswing crane carriage position and swing angle after a positional step input of 3 feet before and after the antiswing signal is applied

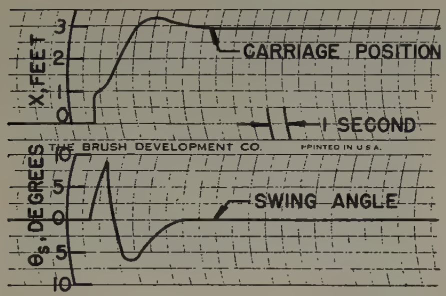


Figure 4. Record of the crane response to a 3-foot step input with the antiswing signal connected

motor for the servo drive, spiral potentiometers to measure carriage position and control knob position, a d-c tachometer generator to provide the viscous damping, and a small synchro to measure the swing angle, θ_s. An electronic amplifier sums these signals and supplies current to the control fields of the amplidyne.

The system can be analyzed or synthesized by any of the well-known feedback techniques. Stability can be achieved rather easily. A qualitative understanding may be based on the law of conservation of energy. If a load is set to swinging as a free pendulum, the stored energy of the mass is constant. To stop the swinging it is necessary to extract this energy without applying any forces to the load except along the length of the cable. This can be achieved by allowing the load to do work on the carriage and thus give up its stored energy. Briefly, the carriage is driven in the direction in which the load tries to pull it and energy is transferred from the load to the carriage. As the load swings from side to side, this action continues until all of the energy of the swinging has been extracted. Referring to Figure 1, assume the load is off the vertical to the left. Since the force in the cable is always along the cable, there will be a horizontal force on the carriage proportional to sine θ_s. If the carriage is driven in the direction of this horizontal force, the load will have done work on the carriage. Since the carriage is driven by a positional servomechanism and since the antiswing signal, θ_s, is equal to zero after the swinging has stopped, the rest position of the carriage will not be affected by θ_s.

Figure 2 shows a block diagram of a system similar to the antiswing crane. In this case, however, the load has rotary inertia and is coupled to the servo output through a relatively weak spring. The action in this case is identical to that of the crane, provided the swing angles are small enough so that the sine of the angle is equal to the angle. Since the two systems are mathematically similar, stability requirements are also similar. It is possible, therefore, in a multiple-cable crane system, to put the entire hoist mechanism on a turret and stop angular oscillations as well as swinging oscillations.

Figure 3 shows a Brush oscillogram of the antiswing crane carriage position and swing angle after a positional step input of 3 feet. The first part of the oscillogram is taken with θ_s signal disconnected. The carriage moves over about 3 feet and the load begins to swing through an angle of about 7 degrees. It continues to swing until the antiswing signal is turned on; the carriage then makes a few motions and the swinging angle dies out to zero.

Figure 4 is a Brush oscillogram of the response of the crane to a 3-foot step input with the antiswing signal connected at all times. Here it will be noted that the carriage does not move quite as rapidly as it did before but moves beyond its rest position and then back. The swing is damped out in about 1 cycle. The final position of the carriage is not affected by θ_s since it is zero after swing stops.

The system outlined in the foregoing is quite stable but some improvement was achieved by adding a lead network in the antiswing signal, θ_s. Further work is needed before the entire system can be built into a working crane. For example, some provision is needed to cut out the antiswing signal when the cable goes slack, and the entire servo system will require safety features to avoid erratic action in case of electronic or wiring failures.

ANTICREEP VARIABLE-SPEED HOISTING DRIVE

It is often desirable to control vertical motion of a load by a continuously variable speed drive, but at the same time it is necessary to cause this drive to stop smoothly and completely when the control is released. With the ordinary

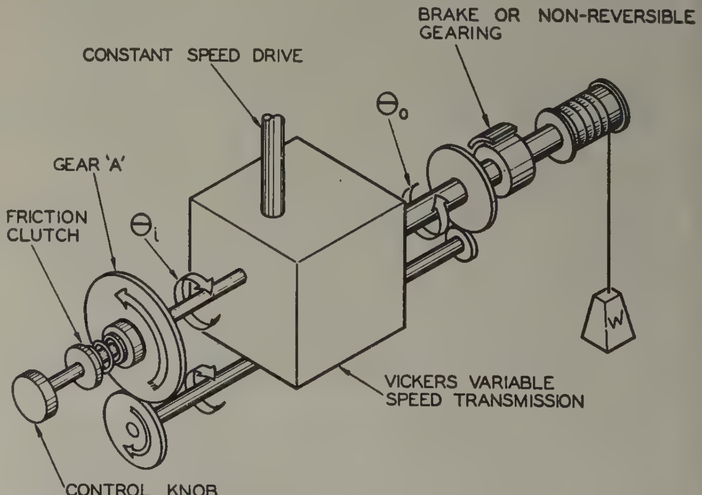

BRAKE OR NON-REVERSIBLE GEARING
CONSTANT SPEED DRIVE
Θo
GEAR 'A'
FRICTION CLUTCH
Θi
W
VICKERS VARIABLE SPEED TRANSMISSION
CONTROL KNOB

Figure 5. The use of feedback from the variable-speed drive to the input control enables the use of the full speed range of this drive

open-loop variable-speed drive it becomes increasingly difficult to cause the output motion to stop as the ratio of maximum to minimum speed control is increased. In other words, the better the variable-speed drive, the more difficult it is to stop it completely or keep it from creeping.

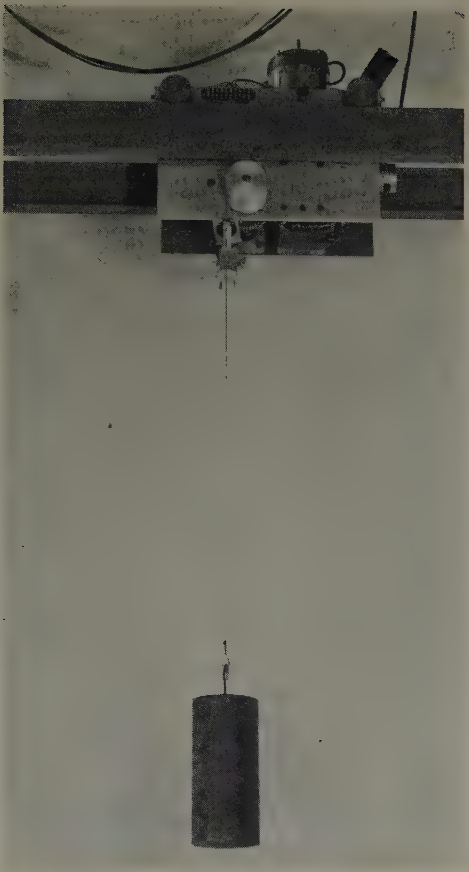
By using feedback from the output of the variable-speed drive back to the input control, it is possible to utilize the full speed range of the variable-speed drive and, at the same time, have it come automatically to a smooth stop when the control is released. Figure 5 illustrates this idea applied to a hydraulic variable-speed transmission. Electric drives also could be connected in this manner.

To utilize the feedback principle as indicated, it is necessary that the input control be in the form of a mechanical motion or angle which establishes an output speed somewhat proportional to the input. Feedback is then applied to this input through a slip clutch and connected so that the feedback always tends to turn the input control in a direction which would cause the output to slow down or stop. To establish a speed, it is necessary to apply a force sufficient to move the control and to overcome the friction in the small slip clutch. When the control is released, the slip clutch drives it back to the zero position and causes the output to stop in a smooth exponential manner.

The feedback arrangement also has the property of resisting or holding a load at the output when no force is applied at the input control. This is brought about since a motion of the output drives the input control in a direction to oppose this motion. Equilibrium will be established when the input control reaches a position sufficient to hold the load.

A synchro repeater can be attached to the input, θ_i, and controlled by a distant synchro transmitter. With this arrangement no mechanical connections are needed between the manual control and the hoisting drive.

Figures 6 and 7 show the laboratory model crane incorporating the antiswing horizontal drive system and the anticreep variable-speed hoisting drive.



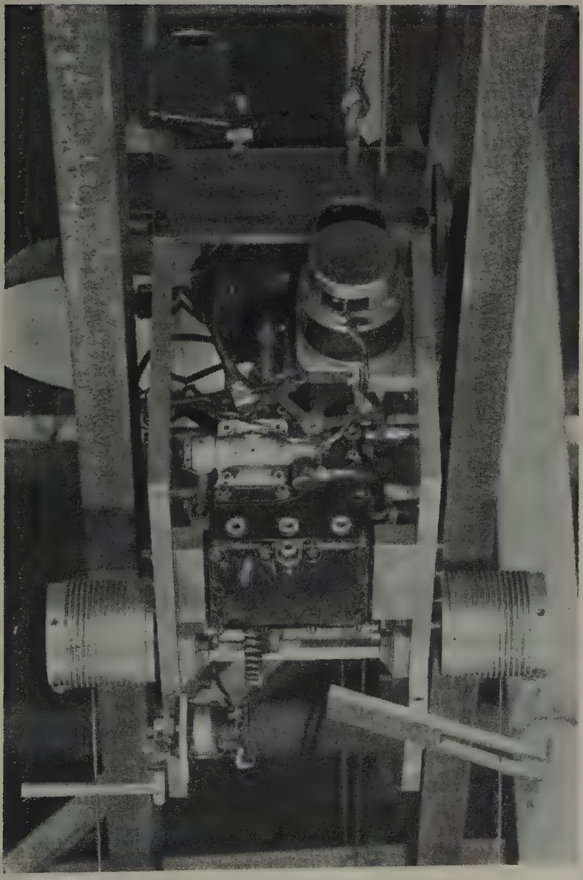


Figure 6 (top). Side view of the laboratory model of the crane in which is incorporated the antiswing horizontal drive system and anticreep variable-speed hoisting drive. Figure 7 (below). Bottom view of the laboratory model of the antiswing crane

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Rocket Research and Industry

Rockets and guided missile research and development will have a wide effect on industry and business in the future, according to L. A. Hyland, vice-president in charge of engineering, Bendix Aviation Corporation.

He gave three instances where guided missile work has been useful already: the designing of faster, stronger, and more precise automatic controls and automatic machine tools; research on upper air phenomena which enables more accurate weather forecasting; and a special Bendix automotive product, not yet announced or placed on the market, which involved a design problem that went unsolved until guided missile know-how was applied.

A great deal of the information derived from guided missile combustion research work, Mr. Hyland said, will be directly applicable to piston engines, as well as coal and oil furnaces.

Flashover Torque of a D-C Generator

O. C. COHO
ASSOCIATE MEMBER AIEE

THE PAST SEVERAL YEARS have witnessed a rapid increase in the use of diesel-electric locomotives. In the course of day-to-day operation, the electrical drive of these locomotives is subject to frequent and severe transient load surges. This type of operation—particularly in a locomotive environment conducive to the accumulation of dirt, dust, oil, and moisture—results in commutator flashing to a degree not encountered in usual d-c machine applications.

Little information has been available in the past regarding the behavior of d-c machines during flashover, particularly in regard to the torque developed during this abnormal operating condition. The results of a series of torque measurements on a 1,600-horsepower traction generator during flashover are here presented.

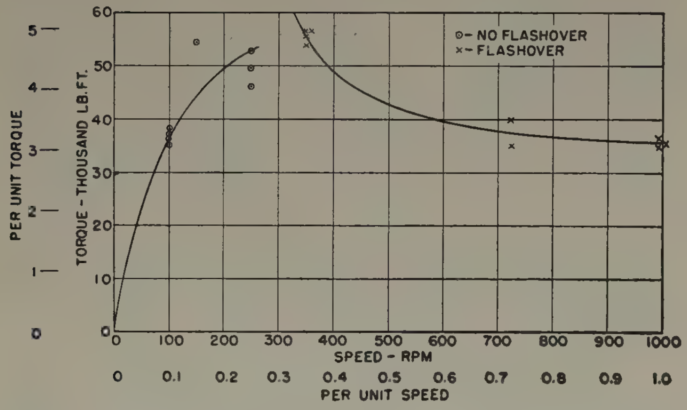


Figure 1. Average torque over 7/60 second versus speed. Full field excitation. Fault resistance 0.000765 ohm

Strain gauge measurements on the generator shaft indicate a wide variation of torque during flashover. After these measured shaft torques were corrected to obtain the air gap torques by introducing the consideration of the generator armature inertia torques, a peak of 11.6 times normal was indicated. This was followed by a minimum of slightly more than normal torque.

This cyclic variation appears to be a significant function of pole frequency. It is probably a result of armature turn flux linkages—trapped in polarity by the short-circuited commutator—passing by the exciting poles. The foregoing torque values were obtained from a flashover produced by a direct short circuit on the machine at full field and 35-per-cent speed (350 rpm).

A series of full field flashovers at various speeds was made. The results are indicated on Figure 1. The shape of this curve is very suggestive of the torque-slip characteristic of an induction motor. This is what might be expected in comparing the behavior of a d-c armature having a short-circuited commutator with that of a squirrel-cage induction-motor rotor. The torque is a maximum at a relatively low speed (slip), and falls off appreciably at the high normal operating speeds.

This series of tests, together with others mentioned in the following, was made without the benefit of strain-gauge indications. Torques were evaluated from deceleration measurements over a discrete time interval—7/60 seconds. Consequently, the results do not reflect the afore-mentioned peak torques. On all tests where comparisons were made, however, it was found that the peaks were, in general, twice the average for this interval. This factor should be considered in interpreting the results.

Saturation and arc behavior are undoubtedly reflected in the effect of initial machine excitation. Figure 2 shows the variation of torque with excitation at normal speed (1,000 rpm). It is evident that above 70-per-cent normal excitation, the increase in torque with excitation falls off considerably.

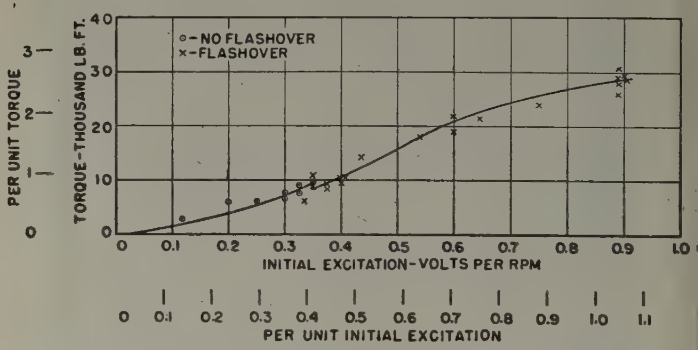


Figure 2. Average torque over 7/60 second versus excitation. Fault resistance 0.048 ohm. Speed 1,000 rpm

A comparison of flashover torques resulting from dead short circuits with those resulting from marginal faults just sufficient to produce flashovers, indicated approximately 25 per cent higher torques for the former case. Considering the fact that the loop circuit resistance is nearly ten times more for the marginal fault than for the dead short circuit, the results indicate that the arc current is by far the dominant component of the armature current.

The operating speed at which flashover occurs deserves primary consideration, and torques appear to be a maximum at the lowest speed at which flashovers can be initiated. As expected, the flashover torques increased with initial excitation, with saturation being of importance at high excitation levels.

Digest of paper 53-83, "Flashover Torque of a D-C Generator," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Operations Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 19–23, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

O. C. Coho is with the General Electric Company, Erie, Pa.

Temperature Classes for Dry-Type Transformers

PAUL NARBUT
MEMBER AIEE

INSULATING MATERIALS currently are classified into classes *O*, *A*, *B*, *C*, and *H* (AIEE Standard Number 1). Although this classification may be adequate as a rough indication of the nature of a material, it does not appear to be adequate for establishing standard operating temperature limits either for materials, or, particularly, for a complete apparatus. The inherent difficulties in establishing these limits are

1. The organic resins, which are used as a bonding agent in composite insulation, have a wide range of thermal stability.
2. The nature of the inorganic component (whether split mica or glass fiber) in composite insulation largely determines the aging properties of insulation, used as a dielectric barrier.
3. The function of the composite organic–inorganic material in the complete apparatus influences its life, whether a dielectric barrier, or just a spacer.
4. The mechanical arrangement of insulation influences its life, confined and supported, self-supporting, or acting as a mechanical support.

This article considers an approach to the solution of the temperature limit problem for dry-type transformers, based on the following principles:

1. Divorce the classification of insulating materials from the classification of complete apparatus.
2. Establish *temperature* as the basis for a classification system of complete apparatus. This system of classification is to be separate and distinct from a classification system for insulating materials.
3. Establish a fairly rigid test code for determining to which one of the recognized temperature classes a given insulation system belongs.

If temperature classification of complete apparatus is established, based on workable tests, the need for rigid temperature limits for materials will be eliminated automatically, in order to avoid existence of double, and in some cases incompatible, standards. It is not to be construed from the foregoing that the accurate knowledge of aging properties of materials no longer will be needed. It will be essential to have this as design information, and as a guide in designing adequate tests for temperature classification of apparatus.

Currently, in addition to the 95-degree-centigrade class for oil-immersed transformers with cellulose insulation, establishment of two more temperature classes for dry-type transformers appears to be most natural: the 150-degree-centigrade class, and the 200-degree-centigrade class. Additional classes may be added later, when justified by the adequacy of the tests and the availability of insulating materials.

Formulation of an acceptable test code for determining temperature class of a dry-type transformer should be based on the following considerations:

1. It should evaluate a complete apparatus as a unit rather than individual materials or parts.
2. It should be functional. The test requirements and the criterion of failure should be based directly on the operating requirements for satisfactory service.

In accordance with the foregoing, as the most direct approach temperature endurance tests should be made using as test samples either transformer models or complete transformers. For large power transformers the cost of using complete transformers for test samples would be prohibitive. Hence, in this case, a resort to the use of models is inescapable.

In determining the form of the test models it must be acknowledged that it is not yet clear in what manner a dry-type transformer will fail as a result of thermal aging. Primarily because of this uncertainty, the test models, in order to yield significant results, must reproduce in true size and quality all of the essential elements of the insulating structure of the transformer. More specifically, they should be constructed in accordance with the following rules:

1. The arrangement of the different components, such as coils, spacers, electrical barriers, layer insulation, and turn insulation should be an essential duplicate of the transformer construction represented by the model.
2. All of the insulating clearances, such as air clearances from the windings to grounded parts and to other windings, thickness of insulating spacers and layer insulation, should be no greater than in the transformer represented by the model. Smaller clearances should be permissible, provided they are sufficient to withstand without flashover the full value of the test voltage.
3. The materials used for the various components of the insulating structure of the model should be identical with those used in the transformer.

To comply with the requirements for a given temperature class, the test samples shall be able to withstand prescribed test voltages and mechanical stresses without failure, following a prescribed period of accelerated temperature aging. The values of the test voltages and the mechanical stresses should represent realistically those which a full-size transformer is expected to withstand in service.

Digest of paper 53-246, "Temperature Classes for Dry-Type Transformers as Determined by Functional Tests," recommended by the AIEE Committee on Transformers and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 15–19, 1953. Scheduled for publication in AIEE *Transactions*, volume 72, 1953.

Paul Narbut is with Westinghouse Electric Corporation, Sharon, Pa.

INSTITUTE ACTIVITIES

AIEE Board of Directors Meets During Southern Meeting in Louisville

The regular meeting of the AIEE Board of Directors was held in the Seelbach Hotel, Louisville, Ky., on April 23, 1953.

The following resolutions were adopted in memory of Past Presidents Gano Dunn, who died on April 10, 1953, and John C. Parker, who died on March 23, 1953:

Resolved: That the Board of Directors of the American Institute of Electrical Engineers hereby expresses, upon behalf of the officers and members, deepest regret at the death of Doctor Gano Dunn (AM '91, M '94, F '12, HM '45), Director 1897–1900 and 1902–05, Vice-President 1900–02 and 1905–07, and President 1911–12, recipient of many of the highest honors in engineering; and that the Board hereby extends sincere sympathy to the members of his family.

Resolved: That, upon behalf of the membership of the American Institute of Electrical Engineers, the Board of Directors hereby expresses its deepest regret at the death of Doctor John C. Parker (AM '04, M '09, F '12), Vice-President 1921–22, President 1938–39, and an outstanding leader for many years in a wide range of engineering activities; and that sincere sympathy is hereby extended to the members of his family.

EXECUTIVE COMMITTEE

Executive Committee actions on membership applications were reported and confirmed, as follows: As of February 26, 1953—24 applicants transferred and 7 elected to grade of Member; 1 Member reinstated; 172 applicants elected to grade of Associate Member; 19 Associate Members reinstated; 45 applicants elected to grade of Affiliate; 166 Student members enrolled. As of March 26, 1953—22 applicants transferred and 4 elected to grade of Member; 2 Members reinstated; 163 applicants elected to grade of Associate Member; 10 Associate Members reinstated; 34 applicants elected to grade of Affiliate; 165 Student members enrolled.

BOARD OF EXAMINERS

Recommendations adopted by the Board of Examiners at meetings held on February 19, March 19, and April 16, 1953, were reported and approved. The following actions were taken, upon recommendation of the Board of Examiners: 28 applicants transferred and 7 elected to the grade of Member; 2 Members reinstated; 1,373 applicants elected to the grade of Associate Member; 14 Associate Members reinstated; 41 applicants elected to the grade of Affiliate; 198 Student members enrolled.

The Board of Examiners submitted 12 proposals for transfer to the grade of Fellow with a favorable recommendation and a recommended citation in each case. The Board of Directors voted to invite the 12 following Members to be transferred to the grade of Fellow:

J. W. Baring, Commonwealth Edison Company, 72 West Adams Street, Chicago, Ill.
Andrew Bodicky, Union Electric Company of Missouri, 315 North 12th Boulevard, St. Louis 1, Mo.
Herbert H. Cox, Department of Water and Power, 207 South Broadway, Los Angeles 12, Calif.
Lanier Greer, Reliance Electric and Engineering Company, 1088 Ivanhoe Road, Cleveland 10, Ohio
E. A. Harty, Rectifier Engineer, General Electric Company, River Works, Lynn, Mass.
F. B. Johnson, Commonwealth Edison Company, 2233 South Throop Street, Chicago, Ill.
R. J. W. Koopman, Department of Electrical Engineering, Washington University, St. Louis 5, Mo.
E. S. Lammers, Jr., Westinghouse Electric Corporation, 1299 Northside Drive, N. W., Atlanta 2, Ga.
R. S. Peterson, Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.
A. R. Schiller, President, Public Service Company of New Hampshire, 1087 Elm Street, Manchester, N. H.
S. R. Warren, Jr., Department of Electrical Engineering, University of Pennsylvania, 200 South 33d Street, Philadelphia, Pa.
George Wrigley, J. E. Sirrine Company, Engineers, 215 South Main Street, Greenville, S. C.

More information regarding the afore-named individuals appears in *Electrical Engineering* in the new department "AIEE Fellows Elected" (pages 648–50).

A petition, signed by more than the required number of members, for the election of Doctor Edwin Howard Armstrong as Honorary Member of the Institute was presented, with the following citation:

For his distinguished contributions to electrical engineering in the form of inventions in the field of regenerative, superheterodyne, and superregenerative radio receivers, frequency-modulation communication systems, and other developments promoting human welfare.

FINANCES

Treasurer Walter J. Barrett, who was unable to attend the meeting, submitted a report for the period January 1 to April 1, 1953, copies of which were distributed.

Chairman Purnell of the Finance Committee reported disbursements from general funds as follows: February, $97,505.93; March, $93,338.58; April, $90,661.40. The report was approved.

Copies of a comparative statement of income and expenses were distributed. It was stated that the income percentages are near those of last year, and that the expenses to March 31 were slightly below the corresponding figures for last year.

The following resolution was adopted to extend the time for payment of dues for the present fiscal year:

Resolved: That the names of members in arrears on May 1, 1953, for dues of the fiscal year which began May 1, 1952, be removed from the active membership list, as required by the Bylaws, and that the time for payment of such dues be extended until further action by the Board of Directors.

ACTIONS AND APPOINTMENTS

After discussion of the various factors involved in holding the meeting of the Board of Directors during the Summer General Meeting on Wednesday, or on Thursday, it was voted that the next meeting of the Board of Directors be held in Atlantic City, N. J., on Thursday, June 18, 1953, and that the incoming officers and the past presidents be invited to the Board meeting and luncheon.

Future AIEE Meetings

Pacific General Meeting
Hotel Vancouver, Vancouver, British Columbia, Canada
September 1–4, 1953
(*Final date for submitting papers—closed*)

Middle Eastern District Meeting
Daniel Boone Hotel, Charleston, W. Va.
September 29–October 1, 1953
(*Final date for submitting papers—closed*)

Aircraft Electric Equipment Conference
Benjamin Franklin Hotel, Seattle, Wash.
September 30–October 2, 1953

Conference on the Application of Motors to Air-Moving Equipment and Symposium on Induction Motors
Hotel Van Orman, Fort Wayne, Ind.
October 6–8, 1953

Conference on Machine Tools
Cleveland Hotel, Cleveland, Ohio
October 14–16, 1953

Textile Industry Conference on Electric Equipment
North Carolina State College, Riddick Laboratories Auditorium, Raleigh, N. C.
October 29–30, 1953

Fall General Meeting
Muehlebach Hotel, Kansas City, Mo.
November 2–6, 1953
(*Final date for submitting papers—July 6*)

AIEE-IRE Conference on Electronic Instrumentation in Nucleonics and Medicine
New Yorker Hotel, New York, N. Y.
November 18–20, 1953

AIEE-IRE-ACM Eastern Computer Conference
Statler Hotel, Washington, D. C.
December 8–10, 1953

The Board confirmed the appointment by the President of the Committee of Tellers, as follows, to count and report on the ballots cast in the election of Institute officers and the ballots on the proposed amendments to the Constitution: Philip Doane (Chairman), Warren H. Bliss, F. G. Khoury, Martin Lennig, T. S. Michaels, R. H. Perry, Carl M. Stuehler.

The Board approved recommendations by the Headquarters Committee for the acquirement of additional space in the Engineering Societies Building, and some rearrangement of parts of the space now occupied.

The Board approved the recommendation of the Committee on Members-for-Life Fund that the fund continue to be used to defray the expenses of Branch prize winners in all Districts incurred in attending the Summer General Meeting. The committee was requested to continue submitting recommendations each year.

Upon recommendation of the Sections Committee, the Board approved the transfer of Klickitat County, Washington, from the territory of the Spokane Section to the territory of the Richland Section, and the transfer of Gulf County, Florida, from the territory of the Alabama Section to the territory of the Mobile-Pensacola Section.

The Standards Committee reported approval of the following Standards:

Revision of Automatic Circuit Reclosers for A-C Distribution Systems, Number *50*

Guide for Operation and Maintenance of Dry-Type Transformers With Class *B* Insulation, Number *53*

Standard Test Code, and Recommended Practice for Induction and Dielectric Heating Equipment, Number *54*

Guide for Temperature Correlation in the Connection of Insulated Wires and Cables to Electric Equipment, Number *55*

Revision of Preferred Standards for and Standard Specification Data for Generators for Large 3,600-Rpm 3-Phase 60-Cycle Condensing Steam Turbine Generators, Number *601–602.*

Revision of D-C Aircraft Rotating Machines, Number *800*

Revision of American Standards Association (ASA) *C5*, Code for Protection Against Lightning, in capacity of a cosponsor

Underwriters' Laboratories Standard for Flexible Cord and Fixture Wire, for submission to ASA.

The Standards Committee reported the appointment of the following representatives on standardizing committees:

Sectional Committee *C2*, "National Electrical Safety Code"—E. W. Oesterreich, representative, to succeed T. H. Haines, resigned

Sectional Committee *C35*, "Rotating Electric Machinery on Railway Locomotives and Rail Cars and Trolley, Gasoline-Electric and Oil-Electric Coaches"—L. L. Johnson, additional representative

Sectional Committee *C40*, "Storage Batteries"—H. N. Stover, chairman, to succeed G. W. Vinal, resigned

Sectional Committee *C55*, "Capacitors"—M. E. Scoville, chairman and representative, to succeed F. V. Smith, resigned

Sectional Committee *C57*, "Transformers"—J. L. Cantwell, representative, to succeed E. B. Paxton, resigned

Sectional Committee *Z57*, "Sound Recording"—L. C. Holmes, representative

ASA Electrical Standards Board—R. S. Burnap, alternate, to succeed H. E. Farrer, resigned

ASA Graphic Standards Board—H. P. Westman, representative, reappointed

AIEE group of Joint AIEE–American Society of Mechanical Engineers Committee on Steam Turbine Generators—L. T. Rosenberg, representative, to succeed S. H. Mortensen, resigned

AIEE group of AIEE–Edison Electric Institute–National Electrical Manufacturers Association Committee on Insulation Co-ordination—E. M. Hunter, representative, to succeed J. E. Clem, resigned; W. L. Teague, alternate, to succeed F. L. Snyder, resigned; J. M. Meador, alternate, to succeed D. D. MacCarthy, resigned; K. H. Kidd, added as alternate; Byron Evans, added as alternate

The Board approved the recommendation of the Committee on Student Branches that the count of Student members for the purpose of determining the $1 per member appropriation be made on November 15, and the second half be sent by February 15. In addition, headquarters is to keep a record of new members joining between November 15 and February 1, and to provide a 50¢ per member appropriation for these new members.

The Board also approved the recommendation of the Committee on Student Branches that the University of Dayton, Dayton, Ohio, be approved for the establishment of a joint AIEE–Institute of Radio Engineers Student Branch. The electrical curriculum at Dayton was accredited by the Engineers' Council for Professional Development in 1951.

Student Prize Winners Visit RCA

Winners of recent AIEE Student Prize Paper Contests visit the David Sarnoff Research Center of the Radio Corporation of America at Princeton, N. J. Representing colleges and universities in AIEE Districts 1, 2, and 3, are, left to right: Theron Usher, Jr., Yale University; D. M. Barger, Johns Hopkins University; L. R. Doyon, Northeastern University; A. E. Franz, Cornell University; D. R. Collins, Cornell University; Benjamin Fisher, College of the City of New York; L. A. DiPaola, Villanova College; C. A. Quinn, Villanova College; A. J. Kane, Villanova College; R. J. Farrelly, Manhattan College. At right is C. N. Hoyler, member of the RCA Laboratories staff

Upon suggestion of the Institute of Electrical Engineers of Japan that the Institute designate as formal guests from the AIEE two scientists who expect to visit Japan and deliver some lectures, the President was empowered to make suitable arrangements.

The following appointments were made:

United Engineering Trustees, Inc.—A. G. Oehler reappointed for a term of 4 years

Washington Award Commission—D. D. Ewing appointed for a term of 2 years

Inter-Society Committee on Corrosion, National Society of Corrosion Engineers—Ray M. Wainwright designated a senior representative and Hugo W. Wahlquist designated representative

Engineers Joint Council—L. F. Hickernell appointed an alternate

The President was authorized to appoint a representative to attend the Centenary Celebration of the Polytechnic School of the University of Lausanne, Lausanne, Switzerland, June 11–13, 1953.

Extensive consideration was given to a report from the United Engineering Trustees, Inc., on the subject "The Future Home of the Engineering Societies," and answers to seven questions were supplied as requested.

Upon approval by members of the Executive Committee, the President appointed Dr. C. G. Suits to represent the Institute on the Committee to Study Functions and Operations of the National Bureau of Standards, with the understanding that the Astin matter be excluded from the terms of reference to the committee. The Board voted that this action be approved.

The President and Secretary were invited to the Annual Dinner of the Engineering Institute of Canada, to be held in Halifax, Nova Scotia, May 22. The President reported that he would be unable to attend. The Board voted that the Secretary be authorized to attend.

The Board voted that the Secretary and Assistant Secretary be authorized to attend the annual meeting of the Council of Engineering Society Secretaries, to be held in Atlantic City, N. J., June 5–6, 1953, within their discretion.

The incoming President or Secretary, or both, were authorized to attend the Conference of Representatives From the Engineering Societies of Western Europe and the United States of America, which is scheduled to be held in Paris, France, September 7–11, 1953.

The Board voted that a message of appreciation of the hospitality extended at the Southern District Meeting in Louisville, Ky., in April be transmitted to the Southern District officers.

An invitation from the Exchange Club of Atlantic City to the Institute to provide a speaker for its luncheon meeting on Wednesday, June 17, to present a message on the contributions of the Institute to the American way of life, was left to the discretion of the President. Past President Everett S. Lee was later designated by President Quarles, and accepted.

ATTENDANCE

Present at the meeting were: *President* D. A. Quarles; *Past Presidents* T. G. LeClair and F. O. McMillan; *Vice-Presidents* W. L. Cassell, W. Scott Hill, M. D. Hooven, E. S. Lammers, Jr., C. M. Lytle, F. W. Norris, J. C. Strasbourger, and W. R. Way; *Directors* F. R. Benedict, R. F. Danner, E. W. Davis, D. D. Ewing, L. F. Hickernell, A. C. Muir, N. C. Pearcy, C. S. Purnell, Elgin B. Robertson, and H. J. Scholz; *Secretary* H. H. Henline; and *Assistant Secretary* N. S. Hibshman.

Summer Meeting Conference Papers Available Upon Request to Authors

A number of authors who presented conference papers at the recent AIEE Summer General Meeting in Atlantic City, N. J., have indicated their willingness to supply copies of these papers upon request. (Conference papers are not scheduled for publication in AIEE *Transactions.*) A list of currently available papers follows. Readers desiring copies should write directly to the respective authors, at the addresses given.

Economic Aspects of European Electric Power Development
P. A. Abetti, General Electric Company, 100 Woodlawn Avenue, Department 16-310, Pittsfield, Mass.

Modern Forced-Air Cooling of Power Transformers
W. D. Albright, Westinghouse Electric Corporation, 469 Sharpsville Avenue, Sharon, Pa.

Progress Report on Semiconductor Definitions and Letter Symbols—Institute of Radio Engineers
Stephen J. Angello, Westinghouse Electric Corporation, Pennsylvania Avenue, Pittsburgh 8, Pa.

Station-Type Air-Blast Circuit Breakers
(K. T. Ashdown, J. A. Oppel, G. L. Couch)
K. T. Ashdown, General Electric Company, 6901 Elmwood Avenue, Philadelphia, Pa.

Engineering Economy as a Tool of Management
Edmund D. Ayres, The Ohio State University, Department of Electrical Engineering, Columbus 10, Ohio

Boiler Protection and Interlocking on the American Gas and Electric System
H. C. Barnes, American Gas and Electric Service Corporation, 30 Church Street, New York, N. Y.

Measurement of Ambient Air Temperature During Temperature Test on Transformers
Martin F. Beavers, General Electric Company, Building 28, Room 204, 100 Woodlawn Avenue, Pittsfield, Mass.

An Outline of the Principles, Skills, and Tools of Management
Ralph M. Besse, The Cleveland Electric Illuminating Company, 75 Public Square, Cleveland 1, Ohio

Trolley Coach Versus Motor Coach—Here's 15 Years of Competitive Operating Costs
L. W. Birch, Ohio Brass Company, Mansfield, Ohio

Crepe Papers and Crepe-Paper Cables for Transformers
(G. Camilli, L. Mulligan, E. L. Crandall)
G. Camilli, General Electric Company, 100 Woodlawn Avenue, Pittsfield, Mass.

An Analysis of an Analogue Solution Applied to the Heat Conduction Problem in a Cartridge Fuse
(A. E. Guile, E. B. Carne)
E. B. Carne, Remington Rand Inc., Wilson Avenue, South Norwalk, Conn.

Forced Outages Rates of High-Pressure Steam Turbines and Boilers—A Progress Report by the AIEE Joint Subcommittee on Application of Probability Methods to Power System Problems
(G. Calabrese, Chairman)
V. Cook, Consolidated Edison Company of New York, Inc., 4 Irving Place, New York, N. Y.

New Carrier-Current Telephone Equipment for Modern Electrical Utility Communications
(P. R. Crooker)
T. Johnson, Jr., Carrier-Current Sales, General Electric Company, 1 River Road, Schenectady, N. Y.

Statistical Analysis in Functional Evaluation of Insulation
John Cybulski, Naval Research Laboratory, Washington 25, D. C.

A New 69-Kv Oil Circuit Breaker for Hig Interrupting Duty
(V. E. Phillips, K. G. Darrow)
K. G. Darrow, General Electric Compan
6901 Elmwood Avenue, Philadelphia, P

Tailoring Ceramic High K Dielectrics for Specif Applications
Robert J. Dew, Jr., American La Corporation, Cherokee Boulevard an Manufacturers Road, Chattanooga, Ten

Mechanical Rectifier Circuits and Transforme Connections
Edward J. Diebold, I-T-E Circuit Breake Company, 19th and Hamilton Streets Philadelphia, Pa.

The Evaluation of Class H Motor Insulatio Systems
(E. Earleywine, J. F. Dexter)
J. F. Dexter, Dow Corning Corporatio Midland, Mich.

Phase System of Magnetic Recording as Used fo EDVAC Drum Memory
(Donald Eadie)
Miss Rachel Albertson, Editor, Engineer ing and Industrial Experiment Statio University of Florida, Gainesville, Fla.

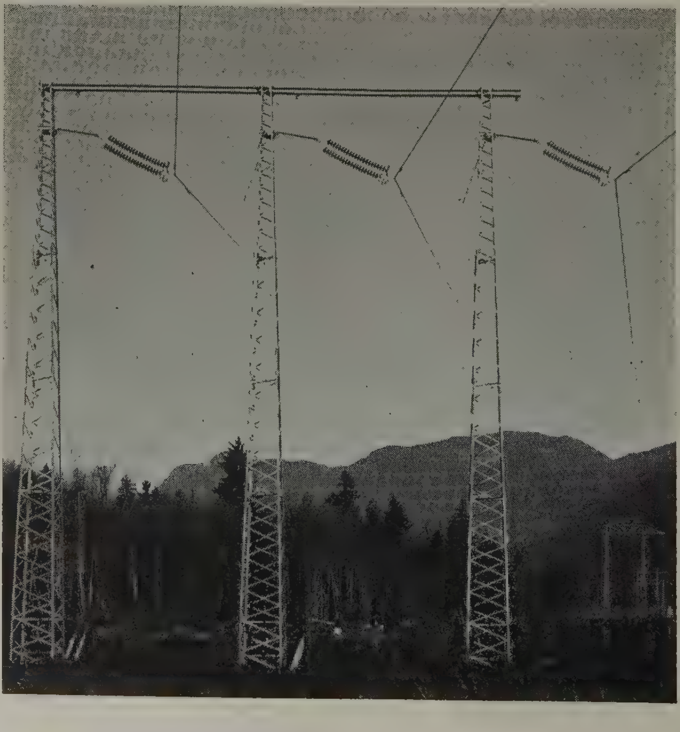
Engineering Plans for Theater Television
Albert J. Forman, *Tele-Tech* and *Electroni Industries*, 480 Lexington Avenue, New York 17, N. Y.

The Quasi-Peak Voltmeter
Charles W. Frick, General Electri Company, 1 River Road, Schenectad 5, N. Y.

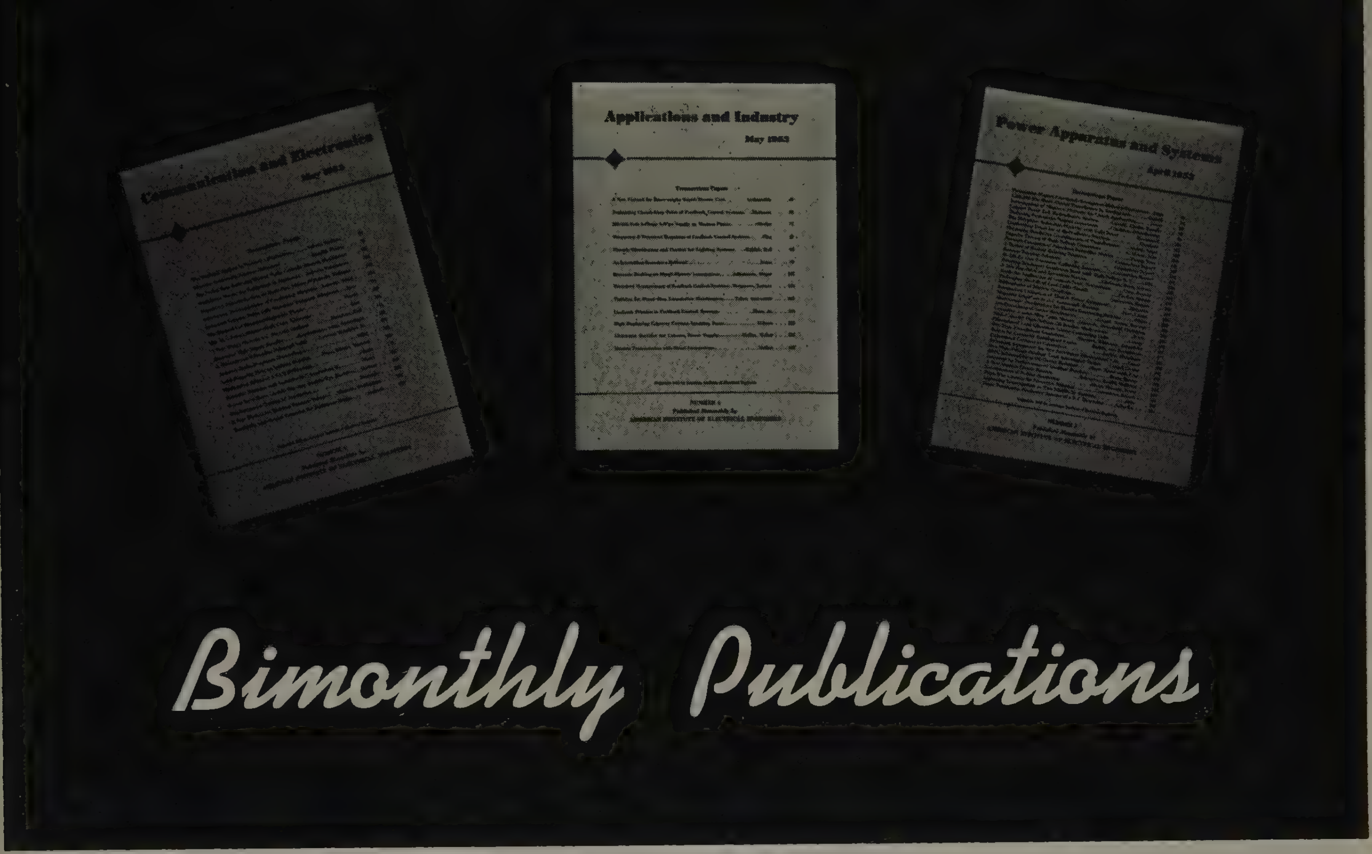
Aging Effects on Insulation Resistance at High Temperatures
(J. L. Fuller, P. H. Kahelin)
John L. Fuller, Reliance Electric and Engineering Company, 1088 Ivanho Road, Cleveland 10, Ohio

(*Continued on page 644*)

Pacific General Meeting Inspection Trip



As opportunity to inspect this transmission line, the first on this continent to be designed for operation at 345,000 volts, will be afforded visitors to the AIEE Pacific General Meeting at Vancouver, British Columbia, Canada, September 1–4, 1953. This 65-mile line, designed for later extension, presently operates at 230 kv and brings power from the British Columbia Electric Company's Wahleach generating station to the metropolitan area of Vancouver


Communication and Electronics
May 1953
Applications and Industry
May 1953
Power Apparatus and Systems
April 1953
Bimonthly Publications

All of the approved papers presented at General and District meetings are available to members in a series of three bimonthly publications. Technical papers sponsored annually by over 40 different Institute committees have been conveniently grouped in these publications:

Communication and Electronics
Applications and Industry
Power Apparatus and Systems

Most papers appear within 2 to 5 months after presentation. Any discussions are correlated with the papers and immediately follow the texts. The months of issue and the subject matter which appears in the bimonthlies are listed below.

Bimonthly publications have become increasingly popular. Availability on an annual subscription basis enables members to receive the publications without filling in order forms.

Members are entitled to receive without charge one of the three bimonthly publications and may subscribe to the other two at a cost of $2.50 each per year. Nonmember subscription price per publication is $5.00 plus 50 cents extra for foreign postage, both payable in advance in New York exchange. Specify the bimonthly publication desired and send all subscriptions to Institute headquarters. College and public libraries are allowed a 25-per-cent discount on nonmember prices; publishers and subscription agencies, 15-per-cent discount on nonmember prices.

Members who have an actual need for some of the papers on a timely basis are urged to subscribe; however, please do not subscribe merely to discard the material unread. Thoughtfulness in this respect will enable a more efficient distribution to fellow members. The same material will be available at the end of the year in cloth-bound volumes to those who have subscribed in advance to AIEE *Transactions* which are issued in three corresponding parts.

COMMUNICATION AND ELECTRONICS
July, Sept., Nov., Jan., March, May

Communication Switching Systems
Radio Communications Systems
Special Communications Applications
Telegraph Systems
Television and Aural Broadcasting Systems
Wire Communications Systems
Basic Sciences
Computing Devices
Electrical Techniques in Medicine and Biology
Electronic Power Converters
Electronics
Instruments and Measurements
Magnetic Amplifiers
Metallic Rectifiers
Nucleonics

APPLICATIONS AND INDUSTRY
July, Sept., Nov., Jan., March, May

Air Transportation
Domestic and Commercial Applications
Land Transportation
Marine Transportation
Production and Application of Light
Chemical, Electrochemical and Electrothermal Applications
Electric Heating
Electric Welding
Feedback Control Systems
General Industry Applications
Industrial Control
Industrial Power Systems
Mining and Metal Industry

POWER APPARATUS AND SYSTEMS
Aug., Oct., Dec., Feb., April, June

Carrier Current
Insulated Conductors
Power Generation
Protective Devices
Relays
Rotating Machinery
Substations
Switchgear
System Engineering
Transformers
Transmission and Distribution

Education
Safety
Research

(*Continued from page 642*)

Wide-Deviation Frequency-Modulated Oscillator
(D. J. Gray, V. P. Gurske, W. E. Morrow, Jr.)
D. J. Gray, Room 22A-216, Massachusetts Institute of Technology, Lincoln Laboratory, Box 390, Cambridge 39, Mass.

Operating Protective Devices for Pressurized Reheat Boilers
G. R. Hahn, Consolidated Edison Company, 20th Avenue and 21st Street, Astoria, N. Y.

Selecting 2,300-Volt Motor Control Equipment for the Petroleum Industry
(L. T. Ellis, A. L. R. Maynard)
J. J. Hannifin, General Electric Company, 1405 Locust Street, Philadelphia, Pa.

Considerations for Discontinuous-Type Power Regulation of Nuclear Reactors
(J. M. Harrer, J. A. DeShong, Jr.)
J. M. Harrer, Argonne National Laboratory, Post Office Box 299, Lemont, Ill.

Basic Theory and Experimental Verification of the A-C Galvanometer
(T. J. Higgins, William Kneen)
Prof. Thomas J. Higgins, Department of Electrical Engineering, Engineering Building, University of Wisconsin, Madison, Wis.

Viewpoint of Test Equipment Manufacturer
(Dr. R. B. Holt)
Miss Rita M. McGrath, Transistor Products, Inc., Snow and Union Streets, Boston 35, Mass.

Equipment Reliability as Applied to Analogue Computers
Herbert Jacobs, Jr., Massachusetts Institute of Technology, Room 20C-206, Cambridge 39, Mass.

Performance Characteristics of Ferrite Recording Heads
J. F. Jewett, Ferroxcube Corporation of America, Saugerties, N. Y.

External and Internal Factors Affecting High-Voltage Bushing Withstand Values
(S. Terpak, D. L. Johnston)
D. L. Johnston, General Electric Company, 100 Woodlawn Avenue, Pittsfield, Mass.

Utility Metering of Resistance Welding Loads
(C. A. Keener, M. A. Faucett)
C. A. Keener, Electrical Engineering Department, University of Illinois, Urbana, Ill.

D-C Transistor Amplifier Employing Junction-Type Transistors
Edward Keonjian, General Electric Company, Electronics Park, Building 3, Syracuse, N. Y.

Generating Plant Costs in 1952
A. E. Knowlton, *Electrical World*, 330 West 42d Street, New York 36, N. Y.

Frequency and Temperature Insensitive Regulated Low-Voltage D-C Power Supplies
(A. B. Rosenstein, Stanley Krauthamer)
Stanley Krauthamer, INET Inc., 8716 South Main Street, Los Angeles, Calif.

A Quarter Century of Trolley-Coach Development
B. J. Krings, Westinghouse Electric Corporation, -4N, Braddock Avenue, East Pittsburgh, Pa.

Present Feasibility of a Nuclear Power Plant
T. G. LeClair, Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.

Fundamentals of Electrical Utility Rates
L. R. Lefferson, Ebasco Services Inc., 2 Rector Street, New York 6, N. Y.

A New Electrode Configuration for the Measurement of Dielectric Strength at Radio Frequencies
(B. P. Kang, C. V. Longo)
C. V. Longo, Department of Electrical Engineering, Rutgers University, New Brunswick, N. J.

Graphic Analysis of Communications Networks
Robert Lyon Mayer, Pacific Gas and Electric Company, 245 Market Street, San Francisco, Calif.

Effect of Voltage and Vibration on Magnet-Wire Insulation
(R. S. Phillips, A. T. McClinton)
A. T. McClinton, Naval Research Laboratory, Washington 25, D. C.

Measurements of Materials With High Dielectric Constant and Conductivity at Ultrahigh Frequencies
(H. P. Schwan, Kan Li)
H. P. Schwan, University of Pennsylvania, H. U. P., 36th and Spruce Streets, Philadelphia, Pa.

Transmitting X-Ray Photographs by Facsimile
(K. R. McConnell)
J. H. Sherman, Times Facsimile Corporation, 540 West 58th Street, New York, N. Y.

Achieving Higher Reliability and Accuracy From Electronic Components by Utilizing Components in Parallel
P. B. Montgomery, Goodyear Aircraft Corporation, Akron, Ohio

The Human Being in Man-Machine Systems
F. R. Naka, Massachusetts Institute of Technology, Lincoln Laboratory, Box 390, Cambridge 39, Mass.

Modern Refinery Distribution System (revised title)
(V. L. Nealy, P. N. Hunt)
P. N. Hunt, Power Engineer, The Texas Company, Post Office Box 98, Westville, N. J.

Viewpoint of Transistor Manufacturer
(J. R. Nelson)
Technical Information Service, Raytheon Manufacturing Company, 55 Chapel Street, Newton 58, Mass.

A High-Output–Low-Demand Resistance Welding Machine
(D. L. Knight, R. S. Phair)
Robert S. Phair, The Budd Company, 2450 Hunting Park Avenue, Philadelphia 32, Pa.

Circuit Action Charts
A. C. Reynolds, Jr., IBM Corporation, Engineering Laboratory, Department 398, Endicott, N. Y.

Large Signal Analysis of Distributed Amplifiers
P. H. Rogers, Electrical Engineering Department, University of Michigan, Ann Arbor, Mich.

Milwaukee Section Holds Annual Meeting

The election of officers for 1953–54 was announced at the recent annual meeting of the AIEE Milwaukee Section. Shown here are the present and newly elected officers and their wives. Standing, left to right: W. R. Ibach, Section Director elect; N. R. Storck, Secretary-Treasurer elect; Alex Paalu, Section Director elect; E. J. Limpel, Chairman; H. C. Brem, Chairman elect; J. E. Deubel, Secretary-Treasurer; and E. J. Seeger, AIEE Director. The ladies are, left to right: Mesdames Ibach, Storck, Paalu, Limpel, Brem, Deubel, and Seeger. Following dinner and the election of officers, R. Renwick of the Milwaukee Better Business Bureau spoke on "Current Frauds and Fakes." The meeting was one of two ladies' night dinner meetings a year in which interesting programs are presented

Designing a Line of D-C Portable Instruments
R. M. Rowell, General Electric Company, 40 Federal Street, West Lynn, Mass.

Review of Television Abroad
(E. A. Laport, C. W. Slaybaugh)
C. W. Slaybaugh, RCA International Division, 30 Rockefeller Plaza, New York 20, N. Y.

Industrial Turbine Selection
John C. Spahr, Westinghouse Electric Corporation, Steam Division, Lester, Pa.

Some Physical Considerations in the Analysis of Transistor Transient Response
(W. F. Chow, J. J. Suran)
Jerome J. Suran, General Electric Company, Electronics Laboratory, Electronics Park, Syracuse, N. Y.

A Discussion of Communications Synchronizing Systems
Frank T. Turner, Western Union Telegraph Company, Water Mill, N. Y.

Maintenance Problems With Reactor Auxiliaries and Instruments
C. B. Wagner, General Electric Company, Manufacturing Department, Richland, Wash.

A "Who's Who" of Organizations Concerned With Electrical Safety
Walter C. Wagner, Staff Engineer, Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia 5, Pa.

Maintenance of Electric Motors (revised title)
(F. H. Walker, W. J. O'Meara)
F. H. Walker, The Atlantic Refining Company, 260 South Broad Street, Philadelphia 1, Pa.

Electrical Safety Standards of the National Electrical Manufacturers Association and the AIEE
H. H. Watson, General Electric Company, 1285 Boston Avenue, Bridgeport 2, Conn.

Nuclear Reactors for Power Generation
(R. L. Witzke, J. M. Stein, E. U. Powell)
R. L. Witzke, Westinghouse Electric Corporation, 801 Walnut Street, McKeesport, Pa.

Why Special Utility Charges for Resistance Welders?
R. E. Young, Public Service Company, 388 East Court Street, Kankakee, Ill.

NORTH EASTERN DISTRICT MEETING

The availability of an additional North Eastern District Meeting paper also has been announced:

Feeder Voltage Regulators
E. A. Sagan, Westinghouse Electric Corporation, 10 High Street, Boston, Mass.

A list of other available papers presented at recent District meetings appeared in the June issue, pages 556–7.

Air-Borne Devices Discussed at Telemetering Conference

The first formal exchanges of telemetering instrumentation information between industrial interests and aircraft and missile research groups occurred at the National Telemetering Conference, May 20–22, 1953, in Chicago, Ill. With the AIEE, the sponsors were Institute of Radio Engineers, Institute of the Aeronautical Sciences, and the Instrument Society of America.

Approximately 300 engineers participated in the six sessions at which 30 papers were presented covering the following subjects: reliability and performance of electronic telemetering in guided missiles and in biophysical research; telemetering problems used in power utilities; different systems of telemetering applied to air-borne equipment; data recording and reduction techniques; and different systems' components were discussed such as a photoelectric roll indicator, crystal-controlled frequency-modulation transmitter, transistors in telemetering equipment, and new ideas on miniaturization and process circuitry. In addition at a luncheon, H. H. Porter, The Johns Hopkins University, described antiaircraft guided missiles, illustrating his talk with recently declassified motion pictures.

Two evening sessions were held. A symposium was conducted by J. A. Doremus, chairman of the conference, on "Mutual Aspects of Performance—Tests, Telemetering, and Industrial Telemetering." Dr. J. E. Hobson, Director of the Stanford Research Institute, made the principal address at the banquet, speaking on the philosophy of telemetering.

After describing the evolution of the science of telemetering, Dr. Hobson covered applications in modern factories where continuous data from various parts of a plant are transmitted to a central control room, where a trained man can follow several operations simultaneously, controlling each one. Experimental rockets shot into the stratosphere contain instruments which send continuous data to the ground. While in both cases the instruments may be similar, industry demands reliability, accuracy, and long service whereas air-borne telemetering devices require peak performance for very short periods.

Dr. Hobson said that telemetering is essentially an extension of the human sensory system. Some limitations on the brain, which can differentiate only a few simultaneous perceptions, also apply to the design and use of telemetering systems. Man cannot comprehend or follow too many instruments, too much simultaneous information. Telemetering systems must be designed for our limitations.

Baker Awarded Medal of Freedom

The Honorable Earl D. Johnson, Under Secretary of the Army, presents the Medal of Freedom to Dr. W. R. G. Baker, General Electric Company vice-president and general manager of its Electronics Division, during recent ceremonies in the Pentagon. Dr. Baker was awarded the medal for accelerating the application of electronics to the solution of Army research and development problems. He led a mission of scientists and industrialists on a mission to Korea in the summer of 1952 to study the problem of utilizing electronic devices and principles to the maximum extent in modern war. According to the citation, Dr. Baker "furnished guidance to the Chief of Staff and the Secretary of the Army which will have a significant impact on the Army's future effectiveness"

Chicago Section Announces Recent Prize Paper Awards

The AIEE Chicago Section has announced award winners in its recent Section and Students Prize Paper Contests.

In the Section papers competition, which was under the direction of Dr. E. T. B. Gross, Chairman of the Papers Committee, first prize went to Nathan Cohn for "A New Method of Area-wide Generation Control for Interconnected Power Systems." In second place was A. M. Hopkin's paper, "Control of Wound-Rotor Induction Motors by Means of Paralleled R-L-C Networks in the Rotor Circuit." "Iron Loss in Universal Motors" by W. E. Wier was the third-prize paper.

The Student papers competition was directed by D. W. Gilman, Chairman of the Students and Young Engineers Committee. The awards in this classification were as follows:

Northwestern Technological Institute

(Undergraduate Competition)

First: L. P. McGrath, "High-Fidelity Sound Reproducers—Their Requirements and Performance"
Second: D. Lund, "An Application of Regression Curves to Electrical Engineering"
Third: N. Polydoris, "An Aircraft Center-of-Gravity Computer"

Honorable Mention: C. E. Bading, "An Electronic Differential Relay"

(Graduate Competition)

First: G. Strull, "Construction of an Electric Analogue for a Water Pipe Network"
Second: C. Nitz, "Vacuum Diode Microwave Energy Detectors"

Illinois Institute of Technology

(Undergraduate Competition)

First: O. Fried, "Electronics in Medicine"
Second: C. M. Knop, "A Glimpse of Noise in Vacuum Tube Amplifiers"
Third: V. F. Bobrowicz, "Differential Protection of a Transformer"
Honorable Mention: M. B. Levine, "Plant Engineering in a Research Organization"

(Graduate Competition)

First: W. Chin, "Electrostatic Unbalance of Untransposed Single-Circuit Transmission Lines"
Second: B. Saltzberg, "A New Method of Solving Nonlinear Systems"
Third: G. T. Flesher, "A Novel Nonlinear Flashing Circuit"
Honorable Mention: M. A. Zavier, "Distance Relaying for Simultaneous Faults"

Akron Is Site of Fifth Annual Rubber and Plastics Conference

The Special Technical Conference on Electrical Engineering Problems in the Rubber and Plastics Industries was held at the Mayflower Hotel in Akron, Ohio, April 20 and 21, 1953. The fifth conference on this subject, this year's meeting covered 2 days, including an inspection trip to one of the large rubber plants in Akron. It was sponsored by the Subcommittee on Rubber and Plastics of the AIEE Committee on General Industry Applications, with the AIEE Akron Section acting as host.

The conference was attended by approximately 200 persons including representatives from engineering concerns, manufacturers, designers, users, and consultants. Papers covered electric power distribution, relay coordinating, electrical drives, differential transformers, grounding of power systems, precision control through servomechanisms, current limiting fuses, and the prospects of use of atomic power. Abstracts of the papers were included as a part of the published program. Also included were a luncheon, and a banquet at which Earl Gulick of the B. F. Goodrich Company spoke.

The committee and conference has as its purpose the stimulation and encouragement of engineering papers and the promotion of standards and recommended practices in the electrical engineering field of the rubber and plastics industry; this conference is considered the most effective way to fulfill this purpose.

Proceedings will be published and may be ordered at $3.50 per copy from AIEE headquarters.

Members of the Rubber and Plastics Subcommittee responsible for the conference were: A. G. Seifried, V. S. Sywulka, R. F. Snyder, K. W. John, J. F. Moore, H. L. Smith, O. M. Bundy, E. H. Gautier, I. E. Andreason, W. S. Watkins, W. J. Secrest, C. E. Robinson, R. E. Seddon, R. S. Gardner (who was the Institute headquarters representative).

Members attending the recent Rubber and Plastics Conference in Akron, Ohio, enjoy the banquet at the Mayflower Hotel

Members of the West Virginia Section who will make arrangements for the Middle Eastern District Meeting are, seated, left to right: G. W. Unangst, Chairman, Technical Programs; H. K. Atkins, Secretary; R. H. Hively, Administration and Co-ordination; R. H. Greame, General Chairman; L. W. Scott, West Virginia Section Chairman; E. D. Knight, Finance. Standing, left to right: B. W. Whittington, Publicity; E. M. Hansford, Technical Programs; J. R. McGinnis, Technical Programs; W. J. Hess, Advance Publicity; W. R. Thorson, Technical Programs. Not present were Harry Lindsey, Advisory; Fred Leinberger, Treasurer; C. R. Stouch, Arrangements; Paul Barlow, Meetings and Inspection Trips; C. B. Talley, Entertainment; J. R. Fox, Honorary Chairman

Middle Eastern District Meeting Set for Charleston in the Fall

The 1953 AIEE Middle Eastern District Meeting is scheduled to be held September 29 to October 1. Headquarters for the meeting will be the Daniel Boone Hotel in Charleston, W. Va.

Subjects of papers to be presented at the meeting will be power, including generation and transmission; chemicals, including electrochemicals; coal mines and management. Several sessions are being planned in each of these groups, in addition to five inspection trips pertaining to these applications.

An interesting entertainment program has been arranged for both members and the ladies. It is suggested that room reservations be made early if accommodations are desired at the headquarters hotel.

Annual Aircraft Meeting Will Be Held in Seattle

Seattle, Wash., will be the host this autumn for the annual AIEE conference on aircraft. This Aircraft Electric Equipment Conference will be held at the Benjamin Franklin Hotel on September 30 and October 1 and 2. Several hundred electrical engineers from all parts of the United States are expected to attend.

Electric equipment and systems for jet bombers and jet fighters will be among the topics of scientific papers. A tentative highlight will be an inspection trip to Boeing Airplane Company, which is currently building *B-47* Stratojets, *B-52* Stratofortresses, and *C-97* Stratofreighters.

AIEE members planning to include the aircraft conference in their vacation schedule will find many recreation opportunities in the Seattle area: salmon fishing, sailing, cruising in the vast Puget Sound, golf, tennis, mountain climbing, or simply touring in the nearby Cascade or Olympic mountains.

Tours, luncheons, and fashion shows will be provided for the entertainment of visiting wives of the engineers.

General Chairman of the conference is T. J. Martin of Boeing Airplane Company; B. F. Hager, also of Boeing, is cochairman. Other committee chairmen are: D. W. Exner, Papers; R. J. Helberg, Banquet; Henry Oman, Publicity; F. L. Strum, Finance; J. L. Converse, Field Trips; J. M. Nelson, Hotel Arrangements; D. C. Betts, Exhibits; F. G. Bayerd, Registration; C. V. Olshan, Hotel Reservations; W. A. Burnett, Transportation; and Mrs. D. W. Exner, Women's Entertainment.

New Officers Elected at Villanova Student Branch

At a May 11 meeting of the Joint AIEE–Institute of Radio Engineers (IRE) Student Branch at Villanova College, Villanova, Pa., newly elected officers for the coming year were introduced. They included J. A. Zator, Chairman; Richard Cuff, Vice-Chairman; George Currie, IRE Secretary; D. J. Louney, AIEE Secretary; and J. W. English, Treasurer.

The meeting was addressed by J. B. Clothier, Jr., assistant professor of electrical engineering at the college.

Kansas City Prepares for Fall General Meeting

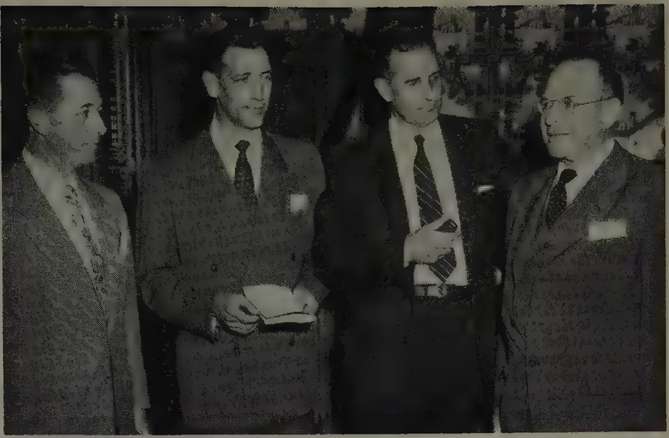
Kansas City, Mo., the "Heart of America," will be the site for the 1953 AIEE Fall General Meeting, November 2–6. Headquarters for the meeting will be at the Hotel Muehlebach.

The technical program will give special attention to the petroleum industry; other features will be announced later. However, there will be the usual inspection and sightseeing trips, smoker, banquet, entertainment, and ladies' program.

The fall is an excellent time to visit Kansas City. Particularly to be recommended is a trip through the beautiful Ozarks during Indian Summer, the latter part of October. In addition to the colorful foliage, there are streams and lakes for boating and fishing and facilities for hiking and riding. Those wishing to extend their trip can attend the American Royal, an international stock show, during the week previous to the meeting.

C. G. Roush, local manager for the Westinghouse Electric Corporation, is Chairman for the Fall Meeting, and S. H. Pollock is Secretary-Treasurer. Many of the hotels in Kansas City are holding rooms subject to placement through Miss Mary Nugent, Chamber of Commerce, 1030 Baltimore, Kansas City, Mo.

Officials of the AIEE Fall General Meeting to be held in Kansas City, Mo., November 2–6, 1953, are (left to right): C. G. Roush, General Chairman; Riley D. Woodson, Vice-Chairman; C. Myron Lytle, Vice-President of District 7; S. H. Pollock, Secretary-Treasurer



Shown at the annual meeting of the New Hampshire Subsection are, left to right: E. W. Boehne, Chairman, Boston Section; J. C. Robinson, Jr., Chairman, New Hampshire Subsection; W. Scott Hill, Vice-President, AIEE; and A. R. Schiller, who was made a Fellow

Schiller Honored at Meeting of New Hampshire Subsection

Avery R. Schiller, president of the Public Service Company of New Hampshire, was made a Fellow of the Institute during the annual dinner meeting of the New Hampshire Subsection of the AIEE Boston Section. The award was presented by W. Scott Hill of Schenectady, N. Y., AIEE Vice-President and Chairman of the North Eastern District. In his address, Mr. Schiller pointed out that the future of New Hampshire depends upon the progress of her industry.

Also present at the meeting was Professor E. W. Boehne of the Massachusetts Institute of Technology, Chairman of the Boston Section, who outlined the procedure for transfer from Subsection status to full Section status in the Institute by the New Hampshire group.

J. C. Robinson, Jr., Chairman of the Subsection, presided at the business meeting, and John Pillsbury acted as the toastmaster.

New officers elected were G. F. Austin, Chairman; B. P. Rines, Vice-Chairman; R. A. Nichols, Secretary-Treasurer; A. F. Patryn, Assistant Secretary-Treasurer; and R. W. Hunt, L. W. Hitchcock, and R. T. Lord, Executive Committee.

Among special guests at the meeting were Victor Siegfried, Director, AIEE; G. H. Crowdes, Secretary, North Eastern District; and AIEE Fellows C. L. Dawes, L. W. Hitchcock, and C. W. Mayott.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Power Division

Committee on Power Generation (*J. A. Brooks, Chairman; J. B. McClure, Vice-Chairman; H. R. Harris, Secretary*). At the request of the Power Division Committee, the Committee on Power Generation has suggested subjects in the power field justifying research investigation. Professor Walter La Pierre of Columbia University, a member of the Committee on Power Generation, canvassed the committee membership and summarized the replies. The original reply letters and the summary have been forwarded to Professor W. A. Lewis, Jr., of the Illinois Institute of Technology, who is the Power Division liaison to the Research Committee. Professor La Pierre classified the suggestions under 14 headings such as, materials, testing, control, excitation, and auxiliary power systems. The variety of subjects included should afford several choices for almost any college or research organization interested in power research.

The Joint Subcommittee on Application of Probability Methods to Power System Problems of the Committees on Power Generation and System Engineering, has prepared a progress report concerning forced outage rates of high-pressure steam turbines and boilers. The work is a continuation of an earlier study of forced outage data collected by committees of the Edison Electric Institute. The present report is confined to horizontal steam turbine-generators operating at pressures of 700 pounds per square inch or greater and rated at or over 20,000 kw condensing or 10,000 kw superposed, and to boilers with continuous rated capacity of 200,000 pounds per hour or more and with outlet pressures of 700 pounds per square inch or greater.

Committee on Protective Devices (*H. R. Stewart, Chairman; A. A. Johnson, Vice-Chairman; E. H. Yonkers, Secretary*). In connection with its revision of Standard Number *28A* on lightning arresters, a working group of the Lightning Protective Devices Subcommittee has been seeking new names for the various classifications of arresters which for many years have been called station type, line type, distribution type, and so on. These names give no clue to the quality of performance of the various classes, and the name "line type" is misleading as to application since these arresters almost always are used in stations and very rarely on lines. The working group has considered six new proposals for arrester classification but finds them all either too complicated or affording insufficient improvement over the present designations. Suggestions from readers for new arrester names will be welcomed to help with a problem which badly needs solving.

Science and Electronics Division

Subcommittee on Energy Sources (*L. W. Matsch, Chairman*). The Subcommittee on Energy Sources of the Committee on Basic Sciences was formed in 1946, under the chairmanship of Dr. W. A. Lewis, to undertake a survey of new developments which may be applied to the generation or conversion of electric energy whether the power involved be large or small. The assignment has been completed and it has been recommended that the subcommittee be discharged with appreciation for its services. The subcommittee sponsored seven conferences in which a total of 25 conference papers were presented. Of these papers, 13 were published in AIEE special publication *S42*, "Sources of Electric Energy"; 19 conference papers were published in *Electrical Engineering*.

The subcommittee membership is as follows: L. W. Matsch, Chairman; W. C. Brown, M. A. Garstens, W. A. Lewis, Walther Richter, J. J. Smith, B. R. Teare, J. D. Tebo, Milton Tenzer.

Pittsfield Wins Tri-Sectional Contest

Members of the Pittsfield team are shown after winning the AIEE Tri-Sectional Speaking Competition held annually among the Lynn, Schenectady, and Pittsfield Sections. Left to right are: W. V. Johnston, P. R. Orens, S. Johnson, P. Fairman, G. L. Jacobson, and Allan Rumpf. Other members of the successful team were C. A. Neumann, A. D. Kline, and J. N. Davis. Pittsfield now has won the competition six times. Contestants are graded on a written paper as well as on their oral presentation

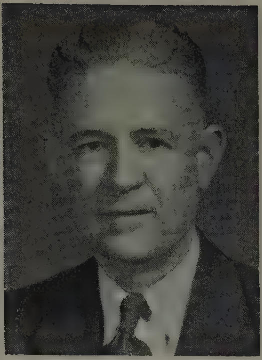
AIEE FELLOWS ELECTED..

Board of Directors Meeting, April 23, 1953

Andrew Bodicky (AM '21, M '37), underground engineer, Union Electric Company of Missouri, St. Louis, has been transferred to the grade of Fellow in the AIEE "for long and outstanding work on important submarine power cable installations and authoritative contributions to the literature of cable engineering." Mr. Bodicky was born in Glogon, Yugoslavia, September 1, 1895, and came to the United States about 1919. He has attended Polytechnic Institute in Yugoslavia and Tulane University and Washington University in the United States. He joined Union Electric in 1921 as junior assistant distribution engineer working on electrolysis and cable fault location and underground estimates. He became assistant distribution engineer in 1924. He has been underground engineer since 1929 dealing with general cable engineering and since 1950 also has been supervisor of underground engineering and estimates concerned with special problems, investigations, and requirements for the underground constructions and maintenance division of Union Electric. During his career with Union Electric he has had direct supervision of 106 submarine cable installations and 33 repair jobs, helped develop a basic theory of interbonding and analysis of various factors involved in the mitigation of electrolytic current from the street railway system, and was responsible for the initial engineering studies and subsequent extension of water cooling of cables and transformers. Mr. Bodicky is the author of several papers on cables. He has served on committees in the Edison Electric Institute and the Association of Edison Illuminating Companies and as a member of the AIEE Committee on Insulated Conductors (1947–53).

Lanier Greer (M '42), consulting engineer, D-C Machinery, Reliance Electric and Engineering Company, Cleveland, Ohio, has been transferred to the grade of Fellow in the AIEE "for outstanding contributions to the design of direct-current motors, as a result of which their utility in railway and industrial applications has been significantly advanced." Mr. Greer was born in Tyler, Tex., November 27, 1901, and graduated from Texas Agricultural and Mechanical College in 1924 with a bachelor of science degree in electrical engineering. After a year's postgraduate work, he joined the student engineer test course at General Electric Company, Schenectady, N. Y., and in 1926 became design and application engineer of d-c motors, generators, and control for gas-electric drive on busses and trucks at the Lynn, Mass., works. He was transferred to the Erie, Pa., works in 1930 as head of electrical design, automotive division, Transportation Engineering Department. He designed and developed d-c generators and motors for railway air conditioning, special lightweight alternators, and d-c generators for portable power plants for the moving picture industry. In 1933 he became design engineer, motor division. When the idea of designing and building a complete standard line of diesel-electric locomotives was conceived, Mr. Greer was given the responsibility of adapting the existing equipment wherever possible and designing new equipment needed. He was also responsible for the design and development of the d-c generator for use with gasoline engines and a portable power plant for use with a 60-inch searchlight. During World War II Mr. Greer was engaged in special engineering development work for the United States Navy involving design and development of high-speed high-power motors. In June 1947 he joined Reliance Electric and Engineering Company, Cleveland, Ohio, as consulting engineer, d-c machinery. Among his accomplishments here have been a new type of d-c motor with octagonal frame, water cooling, d-c motors for mining machinery

Andrew Bodicky



Lanier Greer

Edgar A. Harty

and for operating large deep drawing presses used by the automotive industry. Mr. Greer has served as chairman of the Erie (Pa.) Section of the AIEE (1945–46) and on the Committees on Mining and Metal Industry (1948–53) and Rotating Machinery (1951–53).

Edgar A. Harty (AM '22, M '36), metallic rectifier engineer, General Electric Company, Lynn, Mass., has been transferred to the grade of Fellow in the AIEE "for outstanding research on metallic rectification and fundamental contributions in the field of rectifier engineering." Mr. Harty was born in Constantinople, Turkey, November 13, 1897, and received the degree of bachelor of science in electrical engineering in 1920 from Robert College. He joined General Electric as test engineer on the training course in 1923. In 1924 he became research assistant at the Thomson Research Laboratory of the company with his main work on metallic rectifiers. He was made research engineer in charge of the metallic rectifier research program at the Lynn works in 1928. During this period a pilot plant was expanded into a large manufacturing plant. In 1930 Mr. Harty became design-development and research engineer on metallic rectifiers. His work involved design of rectifiers, transformer design, circuitry, cabinet design, development of applications, development of new rectifiers, process control, guiding research programs, training young engineers, application engineering, and cost reduction. Mr. Harty has presented several articles before technical societies and has obtained more than 15 patents on his work. He is a member of the National Electrical Manufacturers Association, the Massachusetts Society of Professional Engineers, the National Society of Professional Engineers, and the Engineering Society of New England. Mr. Harty is serving on the AIEE Committee on Metallic Rectifiers (1949–53).

Richard J. W. Koopman (AM '36, M '40), chairman, Department of Electrical Engineering, Washington University, St. Louis, Mo., has been transferred to the grade of Fellow in the AIEE "for contributions to the theory and practice of servomechanisms and telemetering as well as his diversity of interest in the several fields of electrical engineering, through which he has become a well-rounded and inspiring teacher and educational administrator." Dr. Koopman was born in St. Louis, Mo., June 25, 1905, and graduated from the University of Missouri in 1928 with a bachelor of science degree in electrical engineering. He received a masters degree from Yale University in 1933 and his doctor of philosophy degree from the University of Missouri in 1942. From 1928 to 1931 he was associated with the General Electric Company, Schenectady, N. Y., doing work on vacuum switches and fuses, mercury-arc rectifiers, testing rotating machinery and industrial control, and revising test manuals and standards. He became an instructor in electrical engineering at Yale University, New Haven, Conn., and later studied at the University of Missouri, being Gregory Scholar in Electrical Engineering there in 1934–35. From 1935 to 1937 he was instructor in electrical engineering, in charge of communication laboratory, Michigan College of Mining and Technology, Houghton. He was named assistant professor of electrical engineering in charge of a-c machinery courses at the University of Kansas, Lawrence, in 1937. He was promoted to associate professor in charge of a-c machinery and power transmission courses and the power laboratory in 1940. While in Lawrence, he served as a consultant for several companies. From 1943 to 1946 he was head, electromechanical section, Curtiss-Wright Research Laboratory (later Cornell Aeronautical Laboratory), Buffalo, N. Y. He was responsible for certain phases of a project to develop a system for telemetering from air to ground various aerodynamic quantities and was also responsible for directing the development of a complete system for radio telemetering aerodynamic quantities from rockets. In 1946 Dr. Koopman became associate professor of electrical engineering at Washington University, St. Louis, in charge of a graduate course in servomechanisms. In 1949 he was named professor and head of the department of electrical engineering. Dr. Koopman is a member of Sigma Xi, Eta Kappa Nu, Tau Beta Pi, American Society for Engineering Education, Instrument Society of America, and the Engineers' Club of St. Louis.

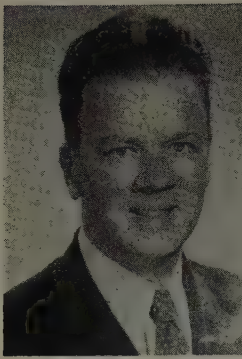
Edwin S. Lammers, Jr. (M '34), electronics engineering supervisor, Westinghouse Electric Corporation, Atlanta, Ga., has been transferred to the grade of Fellow in the AIEE "for many inventions in the field of steel rolling mills and for the advancement of electronics to industrial processes." Mr. Lammers was born in Dallas, Tex., August 11, 1892, and graduated from Texas Agricultural and Mechanical College in 1913 with a bachelor of science degree in electrical engineering. He joined Westinghouse Electric Corporation, East Pittsburgh, Pa., and soon became an industrial control engineer in charge of all steel-mill control for steel-mill auxiliary-motor drives and main rolling-mill drives. In 1919 he became special assistant to electrical superintendent, National Tube Company, Lorain, Ohio, and designed a system for the preventing of the breakage of roll necks on reversing bloom mills. Mr. Lammers was named industrial control supervisor for Westinghouse in 1923 in charge of budget developments, policies, sales, and pricing. He was transferred to Atlanta, Ga., in 1926 as senior industrial consulting and application engineer. He introduced the inertial type of loom motor to textile industry and also the seal-packed ball bearing to lint-free textile motors. He designed and installed the first multimotor slasher drive incorporating automatic tension control on the beam and pioneered the application of small group capacitors on motor terminals for power factor correction. In 1944 he was named to his present position as electronics engineering supervisor. He introduced radio-frequency heating into the Southeast and designed and built the only successful radio-frequency press for the multiple bonding of thermoplastic seals used in the wiring and thermostatic protection of electric blankets. Mr. Lammers is now supervising the consulting and application engineering on microwave links, power-line carrier, with carrier communications, relaying, telemetering, supervisory control, including remote operation of hydroelectric plants and pipe-line booster stations. At present he is pioneering in the application of narrow-

Richard J. W. Koopman

Edwin S. Lammers, Jr.

Ralph S. Peterson

Avery R. Schiller



S. Reid Warren, Jr.

George Wrigley

band frequency-shift carrier to increase the number of available channels on power lines. Mr. Lammers is a member of the Association of Iron and Steel Engineers, Institute of Radio Engineers, and Georgia Engineering Society. Vice-president, District 4 (1951–53), Mr. Lammers is a member of the Board of Directors (1951–53) and the Science and Electronics Division Committee (1952–53) of the AIEE.

Ralph S. Peterson (M '38), line design engineer, Commonwealth Edison Company, Chicago, Ill., has been transferred to the grade of Fellow in the AIEE "for outstanding ingenuity and important contributions in the field of underground transmission and distribution of large blocks of power at high voltages in the form of improved types of insulated cables and cable accessories." Mr. Peterson was born in Chicago, Ill., August 12, 1898, and began his association with Commonwealth Edison in 1922 as a draftsman. He was chief draftsman in 1936–37. Since 1937, Mr. Peterson has been in the line design division of the engineering department and for the past 14 years has been in charge of the division. He is responsible for the location, routing, selection of equipment, and design of electric, mechanical, and structural equipment. The construction of all overhead and underground transmission and distribution lines of the company is under his direction. He is also responsible for the work of a corps of engineers from the various utilities and governmental bodies in the city which prepares unified plans for the installation, relocation, and replacement of overhead and underground facilities involved in major public projects. Some of the outstanding designs of Mr. Peterson are the segmented high-voltage cable, the 69-kv Y junction box, the triangular-shaped conductor, 3-conductor 69-kv oil-filled cable. He also directed the activities of the standards and specification group and the line rating and corrosion group. He conducted tests to determine the thermal properties of soil with reference to cable systems designed to operate close to specified temperature limits. Mr. Peterson is a member of the Western Society of Engineers and has served on the AIEE Committee on Insulated Conductors (1947–51).

Avery R. Schiller (AM '20, M '27), president, Public Service Company of New Hampshire, Manchester, has been transferred to the grade of Fellow in the AIEE "for distinction as an executive of a large electric utility and particularly for engineering design, instruction, and successful operation of a fast growing system, including the pioneering of the first completely integrated binary-cycle (Mercury-Steam) plant." Mr. Schiller was born in Spokane, Wash., May 19, 1890, and received his bachelor of science and master of electrical engineering degrees from Harvard University in 1911 and 1912, respectively. Following his graduation he was employed by Stone and Webster Management Associates, Boston, Mass., and then by Connecticut Power Company, New London, rising to assistant general manager. In 1917 he was superintendent of distribution, Adirondack Electric Power Corporation, Glens Falls, N. Y., leaving that same year to enter the United States Army during World War I. In 1920 he became associated with John A. Stevens, Inc., Lowell, Mass., and in 1924 became assistant to the president, Manchester Traction Light and Power Company. He joined Public Service Company of New Hampshire in 1926 and rose from vice-president in charge of operations to vice-president and general manager and president. Mr. Schiller has played a leading part in designing, constructing, and operating the expanding facilities of the company. Specifically, he has played a major part in design, construction, and operation of a distribution system to serve 125,000 customers, of an integrated transmission network of some 4,500 square miles, and of hydroelectric plants, steam-electric plants, and most recently the first completely integrated binary-cycle (Mercury-Steam) plant ever to be constructed. This plant bears Mr. Schiller's name.

S. Reid Warren, Jr. (M '41), vice-dean, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, has been transferred to the grade of Fellow in the AIEE "for outstanding leadership in the application of electrical engineering principles in the medical field, and for leadership in the promotion of appreciation of such work among both electrical engineers and physicians." Dr. Warren was born in Philadelphia, Pa., January 31, 1908, and attended the University of Pennsylvania, receiving the degree of bachelor of science in electrical engineering in 1928, master of science in 1929, and doctor of science in 1937. In 1929 he became research assistant, Moore School of Electrical Engineering, University of Pennsylvania. At this time work on the analysis of apparatus and techniques used for roentgenography of the chest was conducted under grants by the Medical Research Committee of the National Tuberculosis Association. This work included visits to tuberculosis sanatoria for the purpose of analyzing the apparatus and techniques used in those institutions. This work was continued until 1944 with part-time service associated with other assignments. Dr. Warren became an instructor in electrical engineering at Pennsylvania in 1933, assistant professor in 1939, professor in 1949, and vice-dean in 1951. He also became an associate in radiologic physics, Graduate School of Medicine, University of Pennsylvania, in 1939, assistant professor in 1942, and associate professor in 1947. He is also professor of radiologic physics, School of Medicine, University of Pennsylvania. Dr. Warren has made an extensive contribution to the literature of medical applications of electricity, radiology, and roentgenography. He is a fellow of the American Association for the Advancement of Science; associate fellow, American College of Radiology; member of the History of Science Society, the Society for American Studies, American Society for Engineering Education, The Franklin Institute, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi. Dr. Warren has served as chairman of the Philadelphia Section of the AIEE (1950–51) and on the following Institute committees: Education (1947–53); Therapeutics (1949–51); Electrical Techniques in Medicine and Biology (1951–53, Chairman 1951–53); Science and Electronics Division (1951–53); and Award of Institute Prizes (1952–53).

George Wrigley (M '35), vice-chairman, J. E. Sirrine Company, Engineers, Greenville, S. C., has been transferred to the grade of Fellow in the AIEE "for instituting pioneer and revolutionary engineering changes in the textile industry resulting in the early establishment of the trend to individual motor drive." Mr. Wrigley was born in Macon, Ga., June 25, 1877, and graduated from Alabama Polytechnic Institute in 1897 with a bachelor of science degree in mechanical and electrical engineering. He received the degree of mechanical engineer and electrical engineer from the school in 1899. Following his graduation he joined the General Electric Company, Schenectady, N. Y., on the test course and later was assigned to design and commercial engineering. In 1904 he was in charge of electrical installations, Guanajuato Power Station, Guanajuato, Mexico, for the General Electric Company. He became district engineer, Southeast District, in 1905. He joined J. E. Sirrine Company, Engineers, in 1906 in charge of electrical engineering. He was elected to partnership in the company in 1921. During the past 47 years, Mr. Wrigley's work has consisted of supervision over the design and installation of power and lighting wiring systems in textile plants, bleacheries, dye houses, hydroelectric plants, steam power plants, shipyard facilities, aluminum reduction plants, pulp and paper mills, tobacco plants, schools, churches, and other various types of projects. He was especially active in the conversion of existing textile plants from mechanical drive to electric drive, and later in the application of individual motor drives to textile machines. Mr. Wrigley is a registered professional engineer in South Carolina.

Items on John W. Baring, Herbert H. Cox, and Frederick B. Johnson, also transferred to the grade of Fellow by the Board of Directors on April 23, 1953, will appear in a future issue.

AIEE PERSONALITIES.....

K. B. McEachron (AM '14, F '37, Member for Life), engineering manager, Transformer and Allied Products Division, General Electric Company, Pittsfield, Mass., has been named to a new post in the company, Consultant—Professional Employee Relations. In the new job Dr. McEachron's prime responsibilities will be with the performance, opportunities, compensation, working conditions, and facilities of professional employees at General Electric. He also will be concerned with liaison with professional colleges and will encourage active participation in professional societies by General Electric people. Another aspect of Dr. McEachron's new assignment will be to promote full communication between professional employees and their supervisors and to determine the areas in which professional employees need or want help in self-development and to promote programs to help fill these needs and desires. Dr. McEachron's office will continue to be in Pittsfield. Dr. McEachron received the Edison Medal from the AIEE in 1949 and also has been awarded the Edward Longstreth Medal of the Franklin Institute in 1936, and the New England Award of the Engineering Societies of New England in 1952. He is a member of Eta Kappa Nu. Among the AIEE committees on which he has served are Basic Sciences, Protective Devices, Edison Medal, Executive, Standards, Board of Examiners, Lamme Medal, Publication, Transfers, Planning and Co-ordination, Award of Institute Prizes, Public Relations, and Technical Operations. Dr. McEachron has served as a director (1936–40) and vice-president (1942–44).

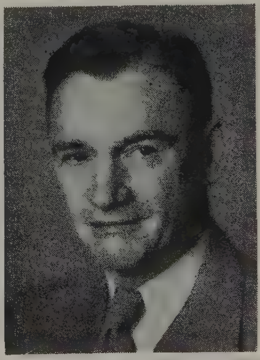
W. B. Kouwenhoven (AM '06, F '34, Member for Life), professor and dean, School of Engineering, Johns Hopkins University, Baltimore, Md., is retiring as dean. Dr. Kouwenhoven has headed the School of Engineering since 1938. He studied electrical engineering at Brooklyn Polytechnic Institute and the Karlsruhe Technische Hochschule at Baden, Germany, receiving his doctorate in engineering from the latter institution in 1913. He joined the faculty at Johns Hopkins at the opening of the School of Engineering in 1914 and has been professor of electrical engineering since 1930. Dr. Kouwenhoven is the author of many papers on electrical measurement, electric welding, magnetic analysis, and electric shock. He is now directing a study of the resistance of electric contacts sponsored by the National Research Council and the Bureaus of Ships and of Air of the United States Navy. Although retiring as dean, Dr. Kouwenhoven will continue his work as professor of electrical engineering at Johns Hopkins. A very active member of the Institute, Dr. Kouwenhoven has served as vice-president (1931–33) and director (1935–39) and on the following AIEE committees: Telegraphy and Telephony (1919–20); Electrophysics (1924–33); Instruments and Measurements (1925–41, Chairman 1933–36); Sections (1925–34, Chairman 1927–30); Co-ordination of Institute Activities (1927–30); Technical Program (1931–47, 1949–50); Safety (1933–53, Chairman 1949–51); Research (1933–41, Chairman 1936–38); Electrochemistry and Electrometallurgy (1935–48, Chairman 1941–43); Award of Institute Prizes (1936–38); Lamme Medal (1938–41, Chairman 1939–41); Standards (1940–50); Institute Policy (1940–42); Therapeutics (1941–50, Chairman 1944–47); Electric Welding (1947–48, 1949–53); Code of Principles of Professional Conduct (1950–53, Chairman 1952–53); Liaison Representative on Standards (1951–53); and Planning and Co-ordination (1952–53). Dr. Kouwenhoven has also served on the National Research Council Division of Engineering and Industrial Research (1945–53); National Fire Protection Association Electrical Committee (1949–50); and National Fire Waste Council (1949–53).

W. J. Seeley (AM '19, F '45), chairman of the electrical engineering department, Duke University, Durham, N. C., has been named Dean of the College of Engineering. Professor Seeley has been chairman of the department of electrical engineering since 1935 and a member of the faculty since 1925. He will assume his new post effective July 1, 1953. Professor Seeley, a native of Shamokin, Pa., for several years has served numerous government and industrial organizations as consultant. During both world wars he served with the United States Navy, conducting experimental research and directing administrative and personnel work. He was named president of the Navy Ordnance Laboratory Technical Reserve in 1945. Professor Seeley was graduated from the Polytechnic Institute of Brooklyn in 1917 and received the master of science degree from the University of Pennsylvania in 1924. He also has done special work at Harvard and Columbia Universities. He taught for 6 years at the Towne Scientific School, University of Pennsylvania, Philadelphia, before joining the Duke staff. Mr. Seeley completed a 2-year term as vice-president of the AIEE in 1951. Earlier he had been chairman of the North Carolina Section and a member of the executive committee of the Southern District. He has served on the following Institute committees: Student Branches (1932–33); Research (1937–40); Basic Sciences (1945–50); Board of Directors (1949–51); Science and Electronics Co-ordinating (1949–50); and as AIEE representative on the Engineers' Council for Professional Development Student Development Committee (1951–53).

B. R. Teare, Jr. (AM '29, F '42), dean of Graduate Studies, Carnegie Institute of Technology, Pittsburgh, Pa., has been appointed dean of the College of Engineering and Science, effective September 1, 1953. Dr. Teare joined the Carnegie faculty in 1939 and was named Buhl Professor of electrical engineering in 1943. In 1950 he was appointed dean of Graduate Studies. A native of Menomonie, Wis., Dr. Teare received his bachelors and masters degrees from the University of Wisconsin. In 1929 he joined the General Electric Company as a student in the advanced course in engineering. In 1931 he became supervisor of the electrical engineering section of the course. In 1935 he decided to enter the teaching field. While serving as instructor, then assistant professor of electrical engineering, at Yale University, New Haven, Conn., he received his doctor of engineering degree in 1937. During World War II he served as an electrical engineer in the Naval Ordnance Laboratory and worked on research problems. In 1947 Dr. Teare was presented the George Westinghouse Award by the American Society for Engineering Education. He is a fellow in the Institute of Radio Engineers and a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and Phi Kappa Phi. A very active member of the AIEE, Dr. Teare has served on the following Institute committees: Communication (1934–36); Electrical Machinery (1937–42); Education (1941–53, Chairman 1948–50); Professional Group Co-ordinating (1948–49); Technical Program (1948–50); Publication (1948–50); and Edison Medal (1951–56).

K. B. McEachron

W. B. Kouwenhoven



W. J. Seeley

E. I. Green (AM '23, F '46), director, Transmission Apparatus Development, Bell Telephone Laboratories, Murray Hill, N. J., has been appointed director of Military Communication Systems. In this capacity, he will have charge of development work on communication systems and apparatus, primarily for military applications. After receiving the degree of bachelor of arts from Westminster College and bachelor of science in electrical engineering from Harvard University, Mr. Green entered the department of development and research of the American Telephone and Telegraph Company. There he was engaged in development work on multiplex telephone and

Fabian Bachrach

E. I. Green

telegraph systems. Since entering the Bell Laboratories in 1934, he has filled various assignments, the most recent being director of Transmission Apparatus Development. Mr. Green is chairman of subcommittee *13* of American Standards Association *C42* and has served on the following AIEE committees: Instruments and Measurements (1942–50, Chairman 1947–49); Standards (1947–50); Technical Program (1947–49, 1951–52); Communication and Science Co-ordinating; (1947–49); Science and Electronics Division (1950–53, Chairman 1950–52); Technical Advisory (1950–52); Liaison Representative on Standards (1951–53); Technical Operations (1952–53); Planning and Co-ordination (1952–53); and Award of Institute Prizes (1952–53, Chairman 1952–53).

C. E. Burke (M '49), manager of sales, Switchgear Department, General Electric Company, Philadelphia, Pa., and **H. F. Hentschel** (AM '43), managing engineer, Panel and Equipment Division, General Electric Company, Philadelphia, have been named general managers of the High Voltage Switchgear Department and the Medium Voltage Switchgear Department, respectively. **V. L. Cox** (AM '28, F '50), manager of engineering, Switchgear Divisions, has been named manager of the Engineering Department. Mr. Burke is a 1926 graduate of the Georgia School of Technology with a bachelor of science degree in electrical engineering. He joined the General Electric Company in 1926 and has had assignments in the Switchgear Division, Philadelphia, Central Stations Division, Schenectady, N. Y., Cleveland (Ohio) Sales Division, Fort Wayne, Ind., and Pittsfield, Mass. Mr. Hentschel joined the General Electric Company in 1925, after graduating from Alabama Polytechnic Institute with a bachelor of science degree in electrical engineering. He came to the Philadelphia division in 1927. Mr. Cox joined General Electric in 1926 on the test course following his graduation from the University of North Dakota. He was assigned to the Philadelphia Works in 1928. Mr. Cox has served on the AIEE Committee on Switchgear (1948–53).

T. L. Mayes (AM '35, M '41), General Electric Company, Fort Wayne, Ind., has been appointed general manager of the Small Integral Motor Department. Mr. Mayes was manager of engineering at the Lynn, Mass., Motor Works before going to Fort Wayne last year. He came to General Electric in 1927 and after assignments in Schenectady, N. Y., and Lynn, Mass., he was transferred to the Oakland, Calif., plant. He worked on motor design application there for 12 years before becoming engineer and superintendent of the section. In 1947 Mr. Mayes became works engineer for the Oakland and San Jose, Calif., operations. Two years later he returned to Schenectady as assistant manager of engineering for the former Apparatus Department. Mr. Mayes received a bachelor of science degree in electrical engineering from the University of California and is a member of The American Society of Mechanical Engineers. **J. H. Behm** (AM '50) has been named manager of engineering for the department. Mr. Behm returned to Fort Wayne in 1952 after a 2-year assignment in Lynn where he was assistant to the manager of engineering of Lynn motors. Prior to that time he had worked in fractional and aircraft motor engineering at Fort Wayne. He joined General Electric in 1929.

F. J. Gaffney (AM '37), general manager, Polytechnic Research and Development Company, Brooklyn, N. Y., has joined the Guided Missiles Division of the Fairchild Engine and Airplane Corporation, Wyandanch, N. Y., as director of engineering. During World War II, Mr. Gaffney headed the Test Equipment Group in the Massachusetts Institute of Technology Radiation Laboratories, Cambridge. After the war, Mr. Gaffney joined Polytechnic Research and Development as chief engineer. He became general manager in 1950. He is a member of the Institute of Radio Engineers, American Physical Society, American Association for the Advancement of Science, and chairman of the United States Commission on Standards and Methods of Measurement of the International Scientific Radio Union. He has been a member of the AIEE Committee on Instruments and Measurements (1947–52).

M. T. Crawford (AM '07, F '22, Member for Life), chief engineer, Puget Sound Power and Light Company, Seattle, Wash., retired March 31, 1953. Mr. Crawford started as a draftsman and designer in 1906 for the Seattle-Tacoma Power Company (one of five systems to be consolidated as Puget Power). He held in succession the titles of assistant engineer, superintendent of transmission, superintendent of distribution, and by 1932, general superintendent. He became assistant chief engineer in 1936 and chief engineer in 1942. Mr. Crawford is a past chairman of the Seattle Section of the AIEE and has served on the following Institute committees: Transmission and Distribution (1916–17, 1919–20, 1924–26, 1927–29, 1936–40, 1941–42); Protective Devices (1936–38); and Insulated Conductors (1947–49).

W. A. Gallotte (AM '41, M '51), engineer, General Engineering Department, Puget Sound Power and Light Company, Seattle, Wash., has become superintendent of engineering. Mr. Gallotte came to Puget Power in 1927 as an engineer. Subsequently he has been a local office manager, a distribution engineer for both overhead construction and underground service in Seattle. He w called to active duty in the United Stat Army in 1942. Upon his return in 1945 H became head distribution engineer in Seatt and then advanced to assistant to the manager, substation construction supervisor, an assistant supervisor. Two years ago H joined the engineering staff as engineer.

M. H. Hobbs (M '37, F '48), manager o switchgear engineering, Switchgear Division Westinghouse Electric Corporation, Eas Pittsburgh, Pa., has been appointed assistan manager of the division. **C. P. West** (AM '20, F '46), manager of switchboard engineering, has been named manager of engineering, Switchgear Division. Mr. Hobbs a graduate of the University of Kansas, ha been with Westinghouse for 31 years. Mr West attended Case Institute of Technolog and joined the Switchgear Division in 1926 Mr. Hobbs has served on the following Institute committees: Protective Devices (1944–45); Switchgear (1947–53); and Safet (1948–49). Mr. West is serving on th Switchgear Committee (1950–53).

C. J. Koch (AM '26, M '45), manager, induction motor engineering section, Mediun Induction Motor Department, General Electric Company, Schenectady, N. Y., has been named manager of engineering for that department. Mr. Koch was one of the firs graduated in the co-operative course in electrical engineering organized by Massachusetts Institute of Technology and Genera Electric. A native of Baltimore, Md., he received his masters degree in 1924 and joined General Electric the same year on the test course of the Induction Motor Engineering Department. In 1939 he was appointed assistant designing engineer and in 1947 became manager of the induction motor engineering section. He has served on the AIEE Committees on Electric Machinery (1946–47) and Rotating Machinery (1947–48).

J. J. Halloran (AM '34, M '46), design engineer, Electro Engineering Works, Oakland, Calif., has been named a partner in the firm. Mr. Halloran became associated with Electro Engineering Works in November 1945. Graduating from California Institute of Technology in 1935, he became associated with the United States Corps of Engineers on power transmission line and electric dredge construction work. In 1940 he entered the Transformer Sales Department of Westinghouse Electric Corporation and later was assigned to Transformer Engineering Department. During World War II, Mr. Halloran was engaged in underwater ordnance development. He is active in the West Coast Electronic Manufacturers Association, having served as West Coast secretary and a member of the Board of Directors.

E. B. Doll (AM '38, M '47), chairman, Physics Department, Stanford (Calif.) Research Institute, has been named director of the Military Effects Group of the joint Atomic Energy Commission—Department of Defense test organization for the 1953 spring atomic series. During the latter part of the war, Dr. Doll was with the Los Alamos (N.

Mex.) Scientific Laboratories and also was associated with the scientific staff which completed plans for operations at Bikini in 1946. Dr. Doll has been with Stanford Research Institute since December 1949, when he resigned as chief engineer for North American Philips Company.

L. W. Long (AM '37, M '44), general manager, Boston Works, Allis-Chalmers Manufacturing Company, Hyde Park, Mass., has been appointed manager of the Switchgear Department. Mr. Long, who continues in his present position, will be responsible for the combined operations of the West Allis (Wis.) Switchgear and Substation Sections. **J. S. Morgan** (AM '39, M '46), manager, Switchgear Section, Milwaukee, Wis., has been appointed assistant manager of the Switchgear Department. Mr. Long has served on the AIEE Committees on Power Transmission and Distribution (1946–47) and Substations (1947–48); and Mr. Morgan has been a member of the Committees on Carrier Current (1947–48) and Industrial Power Systems (1947–52).

Karl Hellmann (AM '39, M '46), electrical engineer, Gibbs and Hill, Inc., New York, N. Y., has joined Hydrocarbon Research, Inc., New York, N. Y., as electrical supervisor in charge of design. Mr. Hellmann was graduated from Brooklyn Polytechnic Institute in 1938 with a bachelors degree in electrical engineering and has done postgraduate work in metallurgy at Yale University and ultrahigh-frequency study at the University of Pennsylvania. He is a registered professional engineer in New York. From 1940 to 1945, Mr. Hellmann was a specialist with the Navy Department in Philadelphia, Pa.

Beardsley Graham (AM '52), assistant director, Stanford (Calif.) Research Institute, and **W. S. Pritchett** (AM '43, M '50), assistant professor of electrical engineering, University of California, Berkeley, have been appointed publicity chairman and arrangements chairman, respectively, for the 1953 Western Electronic Show and Convention. **H. E. Held** (AM '41), Herman E. Held Company, San Francisco, Calif., has been appointed alternate chairman for visitor housing.

Thomas Fuller (AM '47), manager, Chattanooga, Tenn., branch office, Westinghouse Electric Corporation, has been appointed manager of the Westinghouse branch in Atlanta, Ga. **T. J. Woth** (AM '33, M '44), supervisor, central station engineering, has been named Atlanta branch engineering manager. **J. J. Hill** (AM '37), application engineer, Chattanooga branch office, has been appointed manager of that office to replace Mr. Fuller. A new Westinghouse office has been established in Greenville, S. C., with **J. H. Reeves** (AM '40), formerly application engineer, as manager.

J. C. Milne (M '43), manager, Switchgear and Rectifier Department, Electric Construction Company, Wolverhampton, England, has been appointed assistant general manager. Mr. Milne joined the company as rectifier design engineer in 1934, becoming chief rectifier engineer in 1942. He was appointed manager of the Switchgear and Rectifier Departments in April 1950, and will continue in this position along with that of assistant general manager.

F. K. McCune (AM '33, F '49), assistant manager, Engineering Services Division, General Electric Company, Schenectady, N. Y., has been appointed general manager of the Atomic Products Division. He will be responsible for the company's atomic energy activities which include the Hanford Atomic Products Operation, Richland, Wash., and the Knolls Atomic Power Laboratory, Schenectady, N. Y. Mr. McCune, a native of Santa Barbara, Calif., and a 1928 electrical engineering graduate of the University of California, began his career in General Electric in Schenectady the same year as a student engineer on the Test Course. He subsequently held positions in the International General Electric Company commercial department and in the West Lynn (Mass.) Works, where in 1945 he was named assistant works manager. Returning to Schenectady in 1946, he served first as a member of the Apparatus Department design engineering staff and in 1948 was appointed assistant to the general manager of the department. In 1949 he became assistant general manager of the Nucleonics Department at Richland, Wash. In 1951 he returned to Schenectady to serve as manager of engineering of the former Large Apparatus Division and in 1952 was named to his most recent position in the Engineering Services Division. He is a member of the New York State Society of Professional Engineers. Mr. McCune has served on the AIEE Committees on Transfers (1946–48) and Management (1951–53).

R. D. Moody (AM '48) district manager, Allis-Chalmers Manufacturing Company, Los Angeles, Calif., has been appointed manager of the Rocky Mountain Region with headquarters at Denver, Colo. **R. L. Engel** (AM '46), representative, Los Angeles District Office, has been named manager of the Los Angeles office to succeed Mr. Moody. A graduate of the Colorado School of Mines, Mr. Moody joined Allis-Chalmers graduate training course in 1938. He was connected with the company's Knoxville and Chattanooga, Tenn., offices before entering military service in 1941. He was discharged in 1946 and assigned to the San Francisco, Calif., office, where he was named manager in 1947. He has been manager of the Los Angeles office since 1950. Mr. Moody is a member of the American Institute of Mining and Metallurgical Engineers and is vice-president of the Pacific Coast Electrical Association. Mr. Engel has been associated with Allis-Chalmers since 1939 and is a member of the Pacific Coast Electrical Association.

H. G. Rethmeyer (AM '45), district manager of marine, aviation, and transportation sales, Westinghouse Electric Corporation, San Francisco, Calif., has been appointed branch manager of the newly established San Francisco branch office. **M. W. Scolari** (AM '47), application engineer, **George Skipton** (AM '36), application engineer, and **D. F. Roach** (AM '48), application engineer, have been appointed sales supervisors. **D. R. Hoopes** (AM '42, M '47), engineering and service supervisor, Salt Lake City, Utah, has been named San Francisco branch engineering manager. **D. C. Fulton** (AM '39), district machinery electrification manager, has been appointed manager of marine, aviation, and transportation sales to succeed Mr. Rethmeyer. **C. E. Hammond** (AM '46), application engineer, succeeds Mr. Fulton as district machinery electrification machinery. **E. H. Hulse** (AM '41, M '47), consulting and application engineer, was appointed engineering and service supervisor of the Salt Lake City office, replacing Mr. Hoopes. Mr. Hulse is serving on the AIEE Committee on Industrial Power Systems (1950–53).

W. S. Peterson (AM '23, F '46), chief electrical engineer, and **I. L. Bateman** (M '48), assistant chief electrical engineer, Department of Water and Power, City of Los Angeles, Calif., have been appointed to the positions of assistant general manager and chief engineer and chief electrical engineer respectively. Mr. Peterson has served since November 1951 as chief electrical engineer and has been in the department for more than 30 years. Mr. Bateman has been with the department for 26 years, 4 of which were served as engineer in charge of the power operating and maintenance division. Mr. Peterson has served on the following AIEE committees: Power Generation (1945–49); Constitution and Bylaws (1947–53); and Transmission and Distribution (1940–44).

A. A. Jones (M '46, F '51), manager of the Engineering Department, Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y., has returned from a 5-week trip through Europe to investigate manufacturing procedures there. Mr. Jones toured Sweden, Switzerland, Italy, France, and England, exploring techniques and equipment currently in use in the wire and cable field abroad. Mr. Jones has served on the AIEE Committee on Transmission and Distribution (1948–49).

R. E. McDonald (AM '46), director of engineering and maintenance, Braniff International Airways, St. Paul, Minn., has been appointed director of manufacturing for Engineering Research Associates Division of Remington Rand Inc., St. Paul. Mr. McDonald received a bachelors degree in electrical engineering and in business administration from the University of Minnesota in 1940. As a naval officer during World War II, he instructed classes in radar at Harvard University. In 1946 he became a project engineer and later supervisor of aircraft electrical engineering for Northwest Airlines. When he left Northwest Airlines in 1950 he was superintendent of radio-electrical and accessory overhaul. He joined Mid-Continent Airlines as chief engineer and later became director of engineering and maintenance. When Mid-Continent and Braniff merged in 1952 to form Braniff International Airways, Mr. McDonald directed all engineering and maintenance of the northern region. He is a registered professional engineer, a member of the Air Transport Association of America, and has served on the AIEE Committee on Air Transportation (1949–51).

W. A. Brecht (M '39, F '48), consulting engineer to the vice-president in charge, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed consulting engineer for the Atomic Power Division. Mr. Brecht joined Westinghouse in 1922 as a member of the graduate student training course following his graduation from Pennsylvania State College where he received a bachelor of science degree in mechanical engineering. In 1936 he became section engineer of the mechanical section, railway engineering department, and 2 years later was named manager of the transportation engineering department, Transportation and Generator Division. He was named consulting engineer at East Pittsburgh in 1952. Mr. Brecht is a member of the American Transit Association, The American Society of Mechanical Engineers, the Association of American Railroads, and the Western Society of Mechanical Engineers. He has served on the following Institute committees: Land Transportation (1940–53, Chairman 1946–47); Standards (1945–50); Technical Program (1945–47); and as Liaison Representative on the Standards Committee (1951–53).

L. A. Navarro (AM '51), technical writer, Sperry Gyroscope Company, Great Neck, N. Y., has been appointed technical editor, Line Material Company, Milwaukee, Wis. Mr. Navarro received his bachelor of science degree in electrical engineering from the University of North Dakota.

R. L. Walsh (M '36), assistant chief engineer, Universal Atlas Cement Company, New York, N. Y., has been appointed chief engineer. Mr. Walsh joined the company in 1925 in Chicago, Ill., as assistant electrical engineer. In 1929 he became electrical engineer and was appointed assistant chief engineer in 1944. Mr. Walsh is a member of Eta Kappa Nu and the Association of Iron and Steel Engineers. He has served on the AIEE Committees on General Power Applications (1936–38) and Industrial Power Applications (1938–44).

I. L. Auerbach (AM '48), power engineer, Electronics Department, Burroughs Adding Machine Company, Philadelphia, Pa., has been appointed manager, Special Electronic Equipment Department, in the Research Activity of the company. A radar officer with the United States Navy during World War II, Mr. Auerbach received his bachelor of science degree in electrical engineering at Drexel Institute of Technology and his master of science degree in applied physics from Harvard University. Prior to joining Burroughs Research in 1949 he was associated with the Eckert-Mauchly Division, Remington Rand Inc., Philadelphia. Mr. Auerbach is a member of Eta Kappa Nu, the Institute of Radio Engineers, the Association for Computing Machinery, and the Scientific Research Society of America.

OBITUARY • • • • • •

Lawrence Joseph Gorman (AM '11, M '30, Member for Life), Robin Beach Engineers Associated, Brooklyn, N. Y., died April 25, 1953. Mr. Gorman was born in Waddington, N. Y., April 3, 1887, and graduated from Clarkson College of Technology in 1909 with a bachelor of science degree in electrical engineering. After his graduation he was employed in the Testing Department, General Electric Company, Schenectady, N. Y., and as an instructor at Stevens Institute of Technology, Hoboken, N. J. In 1911 he joined New York Edison Company (now Consolidated Edison Company) as a member of the Test Department. He retired from that company in 1951 after 40 years' service as electrolytic corrosion expert. During World War I he served in the United States Army as an officer in a signal battalion. Mr. Gorman was a member of the National Association of Corrosion Engineers Inter-Society Corrosion Committee (1948–53).

Carl Edward Dreher (AM '43), assistant to the president, Westinghouse Electric International Company, New York, N. Y., died May 6, 1953. Mr. Dreher was born in Brooklyn, N. Y., April 2, 1904, and received his degree in electrical engineering from Brown University in 1925. He joined Westinghouse that same year and transferred to the international company in 1928, serving in the traction apparatus and merchandise sales departments. From 1935 to 1946 he worked in Brazil, Chile, and Cuba as field representative and later as regional director. In 1946 he returned to New York as manager of the Western Hemisphere Department. Later he was named assistant sales manager and manager of apparatus sales and America area sales. He was appointed sales manager of the international company in 1948. Mr. Dreher was a member of the International Relations Committee of the National Association of Manufacturers.

John S. Lapp (AM '14, Member for Life), president and chairman of the board, Lapp Insulator Company, Inc., Le Roy, N. Y., died May 1, 1953. Mr. Lapp was born in Honeoye Falls, N. Y., August 6, 1878, and attended the University of Rochester. He became associated with the Locke Insulator Company, Victor, N. Y., in 1896, and from 1904 to 1916 was general manager of that company. In 1916 he formed the Lapp Insulator Company and for 35 years had served as president, general manager, and chairman of the board of directors. Mr. Lapp was a member of the Rochester Engineering Society and a director of the Electrical Manufacturers' Club.

MEMBERSHIP • • •

Recommended for Transfer

The Board of Examiners at its meeting of May 21, 1953, recommended the following members for transfer to the grade o membership indicated. Any objectio to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons fo such objections, signed by a member, must be furnishe and will be treated as confidential.

To Grade of Member

Abrams, M. L., supervisor, switchboard and contro unit, U. S. Bureau of Reclamation, Denver, Colo.
Ashdown, K. T., unit engineer, General Electric Co., Philadelphia, Pa.
Baker, V. B., engineering hdqtrs. staff, Westinghouse Electric Corp., Pittsburgh, Pa.
Becker, H. C., research engineer, school of medicine Tulane University, New Orleans, La.
Beede, C. H., senior power dispatcher, lighting dept., City of Seattle, Wash.
Booth, C. V., electrical engineer, Maurice H. Connell & Associates, Inc., Miami, Fla.
Campbell, G. B., engineer, Southern Services, Inc., Birmingham, Ala.
Clark, W. J., head, engg. dept., Western Electric Co., Duluth, Minn.
Culhane, J. L., engineer, Iowa Power & Light Co., Des Moines, Iowa
Daoud, D. A., chief, transmission & distribution dept., Cairo Electricity & Gas Administration, Cairo, Egypt
Dickson, H. T., engineer, Stone & Webster Engineering Corp., Boston, Mass.
Diggs, R. S., asst. supt., maintenance section, Philadelphia Electric Co., Philadelphia, Pa.
Dillard, J. K., electric utility engineer, Westinghouse Electric Corp., East Pittsburgh, Pa.
Dow, W. K., consulting engineer, 5400 Pare St., Montreal, Quebec, Canada
Drake, R. S., associate engineer, Chattanooga Electric Power Board, Chattanooga, Tenn.
Early, E. D., power pool manager, Southern Services, Inc., Birmingham, Ala.
Eckels, A. R., associate professor, electrical engineering dept., North Carolina State College, Raleigh, N. C.
Ekstrom, I. R., zone supt. of power, Public Service Co., Div. of Commonwealth Edison Co., Evanston, Ill.
Ewing, J. S., electrical supervisor, Reliance Electric & Engineering Co., Cleveland, Ohio
Garrett, J. C., manager, marketing, meter & instrumen dept., General Electric Co., Lynn, Mass.
Gross, F. J., electronic engineer, Civil Aeronautics Administration, Indianapolis, Ind.
Hand, R. C., Sr., electrical engineer, U. S. Department of Interior, Elberton, Ga.
Hebson, J. D., electrical engineer, Federal Power Commission, New York, N. Y.
Howard, J. F., professional electrical engineer, Canadian General Electric Co., Ltd., Peterborough, Ontario, Canada
Judd, H. R., senior design engineer, Consolidated Vultee Aircraft Co., Pomona, Calif.
Markland, H. J., substation design engineer, Public Service Co. of Indiana, Inc., Plainfield, Ind.
Nebe, H. G., chief engineer, *WSMB* Radio Station, New Orleans, La.
Osborne, R. H., electrical engineer, U. S. Bureau o Reclamation, Billings, Mont.
Phillips, E. B., professor of electrical engineering, University of Kansas, Lawrence, Kans.
Picken, D., electrical inspector of factories, Ministry of Labour & National Service, Liverpool, England
Pickens, H. L., manager, Oklahoma City branch, Allis-Chalmers Mfg. Co., Oklahoma City, Okla.
Ritter, F. T., assistant to general sales manager, Roller Smith Corp., Bethlehem, Pa.
Samter, J. H., assistant engineer, Pacific Gas & Electric Co., San Francisco, Calif.
Schuck, C. L., development engineer, General Electric Co., Philadelphia, Pa.
Seels, H. F., flight control superintendent, Sperry Gyroscope Co., Great Neck, N. Y.
Thornton, C. E., electrical engineer, Stone & Webster Engineering Corp., Boston, Mass.
Tileston, H. W., Jr., electrical engineer, Stone & Webster Engineering Corp., Boston, Mass.
Tribble, L. B., chief, utilities planning branch, Holloman Air Development Center, Holloman AFB, N. Mex.
Warren, R. E., head electrical engineer, Libbey-Owens-Ford Glass Co., Toledo, Ohio
Wolgast, L. H., assistant electrical supt., Reynolds Metals Co., Troutdale, Oreg.

40 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before July 25, 1953, or September 25, 1953, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Benington, L. W., Merz & McLellan, Athens, Greece
Molnar, I., Automatic Electric Co., Chicago, Ill.
Wilkie, J. F., National Coal Board, Maltby, Yorks, England

3 to grade of Member

OF CURRENT INTEREST

Pennsylvania Railroad Inaugurates Timesaving Ticket Selling Service

A unique and timesaving system for selling ail tickets and making train reservations has een inaugurated in Pennsylvania Station, ittsburgh, Pa., by the Pennsylvania Rail-oad. Designed to cut drastically the aver-ge time required to make a reservation and urchase a ticket on trains out of Pittsburgh, he system is centered in a new type of Ticket ales and Service Bureau.

The new system, in operation here for the irst time on the Pennsylvania, combines nanual simplicity with electronic equip-nent. Preprinted theater-type Pullman and eserved coach space coupons—one for each nit of reserved space on trains leaving Pitts-urgh—are arranged under the hands of eservation representatives in special racks by rain and date, with different kinds of accom-nodations denoted by coupons of various olors.

ales representative in Ticket Sales and ervice Bureau prepares to transmit Pull-nan space coupons by Western Union ntrafax to the East Liberty Station, where he customer will pick them up. Two oupons are fastened to the cylinder in her and for one continuous transmission

A Ready-Sale Board, visible to the public s well as all sales personnel, shows by letter nd color the accommodations available for rincipal trains for one week in advance. f, for example, a traveler wants a bedroom n *The Pittsburgher* to New York on any day f the week, a glance at the Ready-Sale oard will show whether it is available. If edrooms for that train are all taken, the oard will show every other type of accom-nodation that is available.

When the desired space is selected, the aveler is given a preprinted space coupon, iminating the former time-consuming hand-ritten entries. The space coupons are rinted weeks ahead and placed in readily sible and accessible trays.

Each space coupon shows the type and esignation of accommodation, car number, train, date, and points of origin and destination. The coupons are printed and put on sale in the bureau 6 weeks in advance.

A telephone reservation is indicated by merely slipping a paper cap over a coupon, with the pickup time on it. If the pickup deadline passes, the cap is removed and the ticket is on sale again.

Simplified railroad tickets are printed automatically by a new ticket-issuing machine called the "Ticketeer," again eliminating hand-written entries.

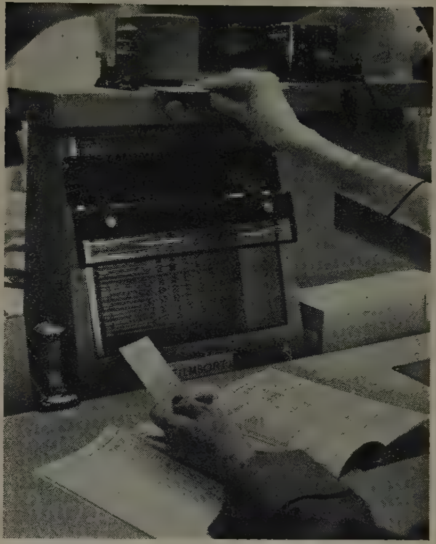
Eight Burroughs Ticketeer machines supply the demand for revenue tickets of all types. A ticket must accompany each space reservation coupon. In addition the Ticketeer prints unreserved coach tickets, commutation tickets, and so on.

A continuous paper roll feeds into the Ticketeer machine. A variety of matrices have been prepared to provide the printing surface from which the blanks on the rolls are completed. The salesman merely inserts the proper matrix into the Ticketeer to print the following information: 1. Class of service; 2. Departure station; 3. Destination station; 4. Limit—1-way, round-trip; 5. Fare, tax, and total amount collected; and 6. Other data required for special ticket form.

In addition, the Ticketeer also automatically prints on the face of each ticket: 1. Date of sale; 2. Ticket number; 3. A 2-letter code for type of payment.

For convenience, the most commonly used matrices are filed in the front counter at each sales position. The least commonly used are filed in the service counter to the rear of the salesmen.

A unique ticket communications system has been established between the central Ticket Sales and Service Bureau and the East Liberty and Sewickley Ticket Offices.


A telephone sales representative uses a Ready-Reference microfilm projector to check fare information. The right hand inserts the slide and the screen shows the 1-way and round-trip fares, tax, and total cost for the various types of tickets and accommodations to specific destinations

Western Union has developed an application of the facsimile process for sending reserved space coupons and other information by wire. By this process, the Central Ticket Sales and Service Bureau in the Pennsylvania Station can send a "picture telegram" to branch offices. Thus far this service is available at the Sewickley and East Liberty Stations.

For example, a customer enters a branch office and requests space for New York. The sales representative fills in an application form. This form is wrapped around a cylin-

Sales representative prepares to insert a matrix in a Ticketeer machine. When the matrix is inserted, the printed ticket rolls out automatically at the slot near her left hand

der in the Intrafax unit. A photoelectric cell provides the impulse whereby the application is transmitted to the central ticket bureau. The sales representative there selects the coupon for the desired space, tears off the stub, marks the destination station, and wraps the coupon around the cylinder of his machine. This machine then sends a facsimile of the space coupon back to the branch office.

Messages and space coupons are reproduced on a special, sensitized paper known as Teledeltos. In the matter of several minutes, the entire transaction has taken place. Actual transmission time for one space coupon is 50 seconds. While this is going on, the branch salesman prepares the customer's rail ticket.

Intrafax is used also to send the branches a periodic picture of the Ready-Sale Board described earlier. By using certain code markings each branch sales representative has a good idea as to availability of space.

In another time-saving move, routes and fares to some 6,500 rail points throughout the country have been microfilmed and filed in such a way that the information can be obtained for any one point within 4 seconds. This includes six different types of fares, the tax, and the total for each.

To speed routine transactions further, a separate sales and service lounge is provided for people who wish to make reservations or purchase tickets for long trips over more than one railroad, and others whose requirements need special handling.

Wire-Wrapping Tool Eliminates Use of Soldered Joints in Electric Equipment

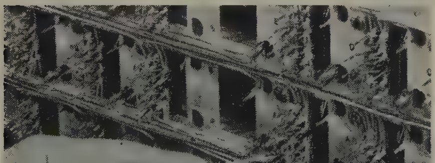
A wire-wrapping tool, jointly developed by engineers of Bell Telephone Laboratories and the Western Electric Company, is said to produce, without the use of solder, a gastight joint between terminal lug and the connecting wire in the assembly of electric, electronic, and electromechanical equipments. It is estimated that in the American communications industry there are about 10-billion soldered joints made each year which can be economically supplanted by this long-sought connecting method.

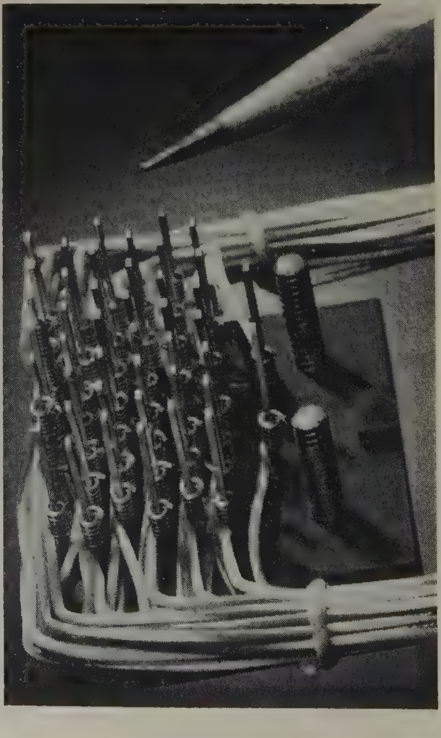
The tool for making these solderless connections is a hand-held gun, either air or electrically operated, that has a rotating spindle with an axial opening that receives the wire terminal and a smaller axial opening into which the skinned end of the connecting wire is inserted. The gun rotates its spindle, which virtually shoots the wire around the terminal in a tight helix, making a firm mechanical metal-to-metal joint. Automatic positioning of the spindle facilitates loading; controlled tension makes highly uniform warps. Rectangular terminals, having sharp edges, are wrapped with about six turns of wire without the application of heat. Contact pressure in the finished connection is at least 15,000 pounds per square inch which results in an indentation at each of the four terminal corners that requires a 10-pound force to strip.

Solderless wrapped-wire connections took 5 years of intensive scientific research to develop. Thoroughly tested by Bell System engineers, the connection is mechanically stable, less apt to break through rough handling or vibration, and has an estimated life expectancy of 40 years. In manufacture, wire wrapping is faster, more uniform, and easier on the operator, than soldering.

Elimination of the soldering phase in assembly operations removes all the disadvantages of that method, the stray solder droppings, the "cold" joints, and the dam
ing of adjacent parts by heat. Clipping
cess wire from a soldered connection, wh
is often a cause of trouble in wire equipme
is not necessary because the wire end is p
of the connection. With the solderless c
nection, terminals can be made smaller
cross section, and spaced more closely
gether. Since the connection requires
minimum of space, equipment can be
duced in size.

Although the Western Electric Compa
does not plan on producing the tool, it will
made commercially available to radio, te
vision, communications, and electrical man
facturing companies through licensed t
manufacturers.





The wire-wrapping tool (above) has a rotating spindle and wraps connecting wire around a rectangular terminal in a tight helix, eliminating the use of solder. (Right) Rectangular terminals about which connecting wire are wound tightly with six turns resulting in an indentation at each corner

Operations Research Society Holds First Annual Meeting

More than 300 people attended the f
Annual Meeting of the Operations Resea
Society of America in Cleveland, Ohio,
May 15 and 16, 1953. The program w
under the chairmanship of Dr. Robert
Rinehart of Case Institute of Technology.

The meetings on the first day, led by
David B. Hertz of Columbia Universi
were concerned with providing a definit
of "operations research," and a descripti
of the type of activity engaged in by ope
tions researchers. Dr. George Kimball
Columbia University claimed the emerge
of a body of basic theory unique to operati
research, naming as members of this gro
search theory, information theory, and
cision theory.

Robert A. Bailey of Lockheed Aircraft
plained the activities of his group in aidi
military planners by use of systems analys
By analyzing proposed systems in light
their future operational requirements, M
Bailey's group provides weapon plann
with a basis for deciding on the most effecti
system. Then, by application of scienti
techniques, quantitative answers to a p
determined measure of effectiveness are
termined.

Operations research people must ha
access to all pertinent information, both i
ternal and external, according to Leroy
Brothers of the United States Air For
They must be allowed to draw conclusi
from their analyses as they appear, rat
than be pressured into producing conc
sions that might suit the political purposes
any single group or individual. He reco
mended that operations research groups
placed outside the regular line of comma
and that they act as advisors to the execut
that uses their results for his decisions.

Technical sessions were concerned w
specific tools used in solving operations
search problems. Sampling theory a
linear programming were two such devi
which came in for their share of attenti
The former is a technique by which a sta
tical sample is taken of all the pertinent
formation in an accounting or clerical pr
lem, and conclusions are drawn about
complete picture on the basis of the samp
In linear programming, a mathemati
model of a physical situation is formulated
that the interrelations of all the pertin
parameters are expressed by sets of lin
equations, appropriate constraints are pla
on the parameters, and the operational c
ditions of the physical situation are det

mined by simultaneous solution of the equations.

The application of the theory of games to operations research was discussed in a session led by Thomas E. Caywood of Armour Research Foundation. This theory describes situations where there are opposing sides, each with various strategies at his disposal, trying to maximize his payoff.

Dr. C. Hollister of Case Institute and Dr. S. B. Littauer of Columbia University reported on the courses in operations research being offered by their institutions. Both have undergraduate and graduate programs.

AGE to Pioneer Steam-Electric Generation Above Critical Pressure

A new boiler and turbogenerating unit to be designed to cross the barrier of the "critical pressure" of steam for the first time in the commercial production of electric power will be the most efficient generating unit ever built and will utilize the unprecedented steam pressure and temperature of 4,500 pounds per square inch and 1,150 degrees Fahrenheit, respectively.

Announcement of plans to build the unit was made by Philip Sporn, president of American Gas and Electric Company (AGE); Alfred Iddles, president of The Babcock and Wilcox Company; and Glenn B. Warren, vice-president of General Electric Company and general manager of its Turbine Division.

After many months of study and preliminary design, the three companies have reached agreements under which General Electric will design and manufacture a 120,000-kw turbine, and Babcock and Wilcox will design and build the boiler for it. The turbine, at 4,500 pounds per square inch, will operate at almost double the present highest steam pressure utilized for power generation. The initial steam temperature of 1,150 degrees will be 50 degrees above the present highest and will be followed by two stages of reheat, the first at 1,050 degrees and the second at 1,000 degrees Fahrenheit. The boiler will be the "once-through," Universal-Pressure type, in which water at 5,500 pounds per square inch is pumped through and changed into superheated steam in a single fast passage through the tubes in the boiler. It will be equipped with the revolutionary cyclone furnaces to insure the rapid and complete burning of the coal and prevent air pollution.

The entire project, cost of which will exceed 12 million dollars, is being engineered by American Gas and Electric Service Corporation, a subsidiary of American Gas and Electric Company. The new unit will be installed at The Ohio Power Company's Philo Plant near Zanesville, Ohio.

In commenting on the project, Mr. Sporn pointed out that it was the consummation of more than 30 years of continuous work and evelopment on the AGE System to bring bout more economical methods of power eneration and that the three companies have o-operated during the past 3 decades on a arge number of other projects looking toward the same objective.

"Many new ideas in turbine, boiler, and plant design will be incorporated and tested n this development," Mr. Sporn stated. mong these are the use of: (1) steam pressure above the "critical pressure" of 206 pounds per square inch; (2) initial eam temperature of 1,150 degrees Fahrenheit; and (3) more than one stage of reheat.

The Universal-Pressure-type boiler does away with the need for the boiler drum and recirculating pumps. "It is this that in part makes the 'once-through' idea so attractive," Mr. Sporn said. "The boiler becomes, in effect, a continuous run of tubing into which water is pumped at one end and out of which highly superheated steam is delivered at the other end." In such a boiler, the feedwater is not delivered to a central drum. Instead, it passes directly from a newly designed feed pump through the boiler unit and is heated and converted to superheated steam at 1,150 degrees, passing through the boiler and superheater just once.

"The successful development of power generation at this new plateau of higher pressures and temperatures will make possible in time still higher pressures and temperatures and additional reheats and resulting efficiencies hardly visualized a few years ago. Efficiencies of conversion of the heat in fuel into electric energy of the order of 50 per cent are distinct possibilities. Certainly they loom on the horizon."

The new Philo Plant unit will be a developmental model and relatively small as modern generating units go. However, to cross the barrier of critical pressures, new concepts of turbine design will be required for this machine. Its 120,000-kw capacity will increase net generating capacity of Philo Plant, one of Ohio's largest, to 495,000 kw. It will replace, and use the same building now occupied by, a 40,000-kw unit built in 1923.

Mr. Sporn recalled that this original unit was the first 600-pounds-per-square-inch steam-electric turbine operating on the reheat cycle to be installed in the United States. "In its day, this installation constituted a very significant advance in the economics of power generation, the full development of which has led to the high standards of capital and thermal efficiencies that are possible today, 3 decades later, in modern power plants operating below the supercritical pressures. We are equally sanguine about the advances that will follow from this new development in supercritical pressures, higher temperatures, and multiple reheat."

Future Meetings of Other Societies

American Transit Association. Annual Meeting. August 10–12, 1953, Hotel Biltmore, Los Angeles, Calif.

Congress of Radiology. 7th International Congress. July 19–25, 1953, Copenhagen, Denmark

International Union of Pure and Applied Physics. Colloquium on Cosmic Rays. July 5–11, 1953, Bagneres de Bigorre, France

Institute of the Aeronautical Sciences. Annual Summer Meeting and Honors Dinner. July 15–17, 1953, Institute of Aeronautical Sciences Building, Los Angeles Calif.

Society of Automotive Engineers. International West Coast Meeting. August 17–19, 1953, Georgia Hotel, Vancouver, British Columbia, Canada

West Coast Electronic Manufacturers' Association and 7th Region of the Institute of Radio Engineers. Western Electronic Show and Convention. August 19–21, 1953, San Francisco Civic Auditorium, San Francisco, Calif.

Du Mont Laboratories Opens Cathode-Ray Instrument Plant

The manufacture of precision electronic instruments in modern plant facilities and by up-to-date manufacturing methods have been provided by Allen B. Du Mont Laboratories, Inc., in its new Cathode-Ray Instrument Division plant at 760 Bloomfield Avenue, Clifton, N. J., which was officially opened recently.

Constructed according to the most modern industrial concepts, the new Du Mont plant contains all of its office, laboratory, storage, and production facilities on one floor. The production floor is laid out through the center of the building in order to provide a "straight-through" production flow.

The new Du Mont plant has been designed to provide the most efficient "straight-through" operating and production flow possible. The manufacturing cycle begins at the west end of the building and runs through to the east end, with receiving and shipping areas located at opposite ends of the plant.

At the west entrance to the 525-foot-long building is a set of six truck loading docks and a receiving area of 3,700 square feet. The receiving area includes an incoming inspection section. From this point approved component parts are forwarded to the general stores area, which includes more than 10,000 square feet of parts storage space.

Instruments are assembled by stages, moving through the production area from the west end. Subassemblies are wired, inspected, and tested, then assembled and wired onto larger chassis along the production route. Incorporated into the assembly areas are a number of test and inspection sections, including a complete finished inspection installation. Each stage is carefully checked, and the final product is given exhaustive tests and inspection before it is finally packed for shipment.

The plant's shipment area also includes six truck loading docks, as well as space for packing and temporary storage.

In order to accomplish this "straight-through" production flow, the Du Mont instrument plant has been designed with offices and laboratories ranged along the south side of the building. Engineering offices and laboratories, including a modern technical library and a specially equipped optical laboratory, stretch along this side of the building and cover a total area of more than 14,000 square feet. The engineering laboratories are provided with complete facilities, including a model shop.

Sales and management offices are located toward the east end of the building, and an instrument service shop has been set up in this section of the plant. The Quality Control Laboratory, which constantly checks finished instruments, subassemblies, and even individual components, is located adjacent to manufacturing and engineering sections. This laboratory is assigned the responsibility for maintaining Du Mont quality and performance, and is one of the most carefully managed quality control installations in the country.

The entire building is serviced by a sprinkler system for efficient fire protection, and the over-all lighting is provided by hot-cathode overhead lamps. Cold-cathode lighting is provided immediately above the workbenches to eliminate eyestrain.

The new Instrument Division plant, which adjoins Du Mont's Cathode-Ray Tube Plant, is also served by a railroad siding, connected by a spur to the Newark branch of the Erie Railroad. Nine loading doors open from the north side of the building onto the siding to facilitate efficient loading and unloading operations.

Work was begun in August 1952.

Reports to AEC Made Available on Nuclear Power Reactor Technology

The declassified versions of reports made to the Atomic Energy Commission (AEC) by four separate teams of nongovernmental industrial representatives who spent a year inside the atomic energy program appraising the prospect for private industrial participation in joint production of electric energy and fissionable material from reactors, are now available. The appraisals included examination of both technical and economic problems involved in production from nuclear reactors of electric energy for industrial and commercial use. These declassified versions represent only about one-fourth to one-third of the bulk of the classified reports. The information they contain was selected for its value to engineers and others interested in the nuclear power outlook in so far as this was possible within the limits of the Commission's current declassification policy.

These four groups were: Commonwealth Edison Company and Public Service Company of Northern Illinois; Dow Chemical Company and Detroit Edison Company; Monsanto Chemical Company and Union Electric Company; Pacific Gas and Electric Company and Bechtel Corporation.

The agreements, which were considered a first step toward possible industrial participation in nuclear power development, provided for the four groups to conduct surveys and studies of reactor technology in order to (1) determine the engineering feasibility of their designing, constructing, and operating dual-purpose reactors to produce fissionable material and power; (2) examine the economic and technical aspects of building such reactors in the next few years; (3) determine the possible research and development needed; and (4) recommend industry's role in designing, building, and operating such reactors.

The companies assumed all costs incurred by their groups. The AEC made available to them the pertinent literature on reactor technology and made it possible for study group personnel to confer with Commission and contractor scientists and engineers on classified as well as unclassified matters. Twelve months were allowed for completion of the studies.

The reports of necessity contained restricted data. Within a short time copies were distributed to qualified reactor scientists and engineers at different AEC installations, and in October 1952, restricted data condensed versions were published in a classified AEC periodical.

The groups understood that declassified versions of their results were likely to be publicly released, in accordance with AEC policy for dissemination of unclassified and declassified atomic energy information. One object of this publication of the reports is to convey as much information as possible to a number of business firms who were not able to put a study team in the field.

This committee affirmed the Commission's judgment that open publication of much of the information would make a valuable contribution to the advancement of reactor technology and to the major objective of securing greater industrial participation in reactor development.

The reports are not AEC reports. They are reports of the industrial firms on their separate assessments of a portion of the atomic energy enterprise. However, they were made according to certain conditions, one being that the groups should consider the possibilities for dual-purpose reactors. Consequently, the designs settled on here are not necessarily those which would have been selected had the studies been directed toward power-only reactors with the plutonium produced having but fuel value.

Another is the requirement of the agreements specifying studies of designs for reactors that might be built within the next few years. Thus the companies for the most part directed their efforts to conservative concepts, components of proved design, and conditions reasonably certain of early fulfillment.

The material contained in the report also does not present a balanced picture of the original reports, owing to security limitations. Very little specific reactor design and economic data could be included. In spite of these limitations, it is felt that the release of these shortened reports will provide a helpful, even though fragmentary survey, of the promise as well as the problems facing those who have an interest in the generation of electric power from nuclear fuel.

All four groups concur in the belief that dual-purpose reactors are technically feasible and could be operated in such a fashion that the plutonium credit would reduce the cost of power. Conversely, all agree that no reactor could be constructed in the very near future which would be economic on the basis of power generation alone. As a final comment all four groups expressed a willingness and a desire to continue their efforts with more detailed studies and component development.

The combined report can be obtained for 25¢ from the Government Printing Office, Washington, D.C.

Westinghouse Breaks Ground for New Atomic Equipment Plant

Ground was broken near Pittsburgh, Pa on May 5, 1953, for a factory that will buil parts for atomic power plants.

Believed to be the first privately finance atomic manufacturing plant, the multi million-dollar facility will house the newl formed Atomic Equipment Department o the Westinghouse Atomic Power Division located in Harmar Township approximatel 1 mile northeast of the Allegheny Valle Interchange of the Pennsylvania Turnpik On the 40-acre plot, construction now wi begin on a 1-floor manufacturing plant o approximately 87,000 square feet.

Expected to employ initially some 20 people and ultimately perhaps many time that number, the plant will engineer, manufacture, and sell products which have bee developed for atomic power plants.

Westinghouse, since the end of 1948, ha been engaged in development and construction of an atomic power plant for the nation's first atomic-powered submarine, an now also holds a development contract for similar power plant to drive a large nava vessel such as an aircraft carrier. The experimental, land-based model of the Westinghouse atomic submarine engine alread has "successfully entered its first phase o operation," it was announced by the Atomi Energy Commission on March 31.

The new plant is expected to be complete and ready for occupancy this year, accordin to William C. Miller, manager of the Atomi Equipment Department, who also participated in the ground-breaking ceremonie He indicated that the work to be done ther will involve no hazard whatever to the surrounding area and will be "primarily desig and mechanical operations."

Ultrasonic Radar Trainer Used in Training Crews by Air Force

Development of a new device for the bombardment and navigation training withou actual flight of aircraft observers of Ai Force air crews was announced recently b the United States Air Force's Air Researc and Development Command.

With this ultrasonic radar trainer, identified as the *AN/APQ-T1*, future air crews wi be able to become familiar with flight problems, including targets, anywhere in th world while still on the ground in this country. It was designed and built for the Ai Force by American Machine and Foundr Company's Electronics Division, under th supervision of equipment technicians at th Air Research and Development Command Wright Air Development Center.

It offers advantages which will expedit Air Force training programs. These are increased safety in training due to the reduction of required flight time; increased utilization of training time resulting from use o the device on a shift basis and for the simultaneous training of the students involved i the bombing problem; reduction of trainin expenses by releasing aircraft and personne for other duties; and increased effectivenes of personnel trained with this device.

Designed primarily for advanced trainin of aircraft observers possessing a 10-yea experience level as bombardiers, navigator and radar specialists, the new unit will enabl one man to become proficient in all the duties formerly performed by three men of a bomber's crew—the radar operator, the bombardier, and the navigator.

The skills and almost automatic reflex actions that effective navigation and bombing demand can be acquired with the radar trainer without the costly hours of actual flight formerly required. Housed in its own permanent building, the equipment can be used to train bombing crews in complete bombing missions. Also, when used with an instrument flight trainer, co-ordinated crew training is possible. Optical bombing techniques also will be taught with the visual bombing simulator which is a part of this trainer.

Employing intricate computers and the same instruments as found in aircraft, the trainer will present to air crew personnel the identical situations and problems that would be met in actual flight. In addition, it records competence in coping with them. Not only does the trainer simulate computer functioning, instrument data and radar operation but it also introduces friendly beacon signals and simulates enemy radar jamming signals to authenticate the problem.

Air-borne radar equipment and actual aircraft instruments are set up in the trainees' booths just as they would be in a bomber. For bombardment training, a modified optical bombsight produces a realistic ground picture in the visual bombing simulator. Manipulation of controls provides the same results as would the same controls in an actual aircraft.

The trainer has its own permanent housing, permitting a greater degree of control over temperature and humidity, and allowing for more comfortable operation.

The fact that there is a ratio of 200,000 to 1 between the speed of electromagnetic waves in air and the speed of ultrasonic waves in water is the basic principle that makes possible the operation of the *AN/APQ-T1* trainer. As a result of this ratio, it is possible to simulate radar flight by moving an ultrasonic transmitting and receiving apparatus over a reduced scale terrain contour map of a portion of the earth's surface.

The map, which is only 1/200,000th the size of the area it represents, is submerged in a tank of purified water held at a constant temperature in order to keep the scale factor constant.

Above the map, but also submerged in the water, is a simulated radar antenna, the position of which can be controlled and maneuvered by the instructor-director, at a control console, acting as the aircraft's pilot.

Motion of the radar antenna directed by the instructor from point to point above the map simulates the flight of a bomber. Instead of sending out radar pulses, however, it transmits pulses at ultrasonic frequencies. These travel at a much slower speed than radar pulses. Consequently the scale of the map can be so greatly reduced that an area representing about 360,000 square miles can be represented in a portion of the self-containing trainer building 3,500 square feet in area.

In all respects except speed, the sound pulses behave like radar pulses. They strike the terrain and are reflected back, converted, and displayed on the trainee's screen.

As part of the navigation setup, the trainees can see on their radar screens a virtually perfect simulation of what would be observed on a training—or combat bombing—flight.

To reproduce actual conditions still further, the instructor can introduce such realistic factors as ground-based radar beacon signals and enemy jamming effects.

The flight path of the bomber is recorded automatically on two plotting boards. Scaled to correspond to the size of the map, one navigation board shows how well the trainee plots his course. The other records the trainee's bombing accuracy.

Bombardment training begins as the plane approaches the target area. The bombing station in the trainer provides equipment indistinguishable from an actual bombsight of the latest design. On the bomb run, the trainee can observe on his instruments a view corresponding to what he would see if in the air. Effects of clouds and wind can be reproduced by the trainer. When the bomb-release button is pressed, the trainer automatically computes the path a bomb would take if dropped at that point.

The second plotting board records the flight path of the simulated aircraft in the region of the bombing operation. The bomb release point and the bomb impact point are both recorded on the board enabling the trainee's performance to be rated.

NBS Develops Simple Magnetizer for Charging Permanent Magnets

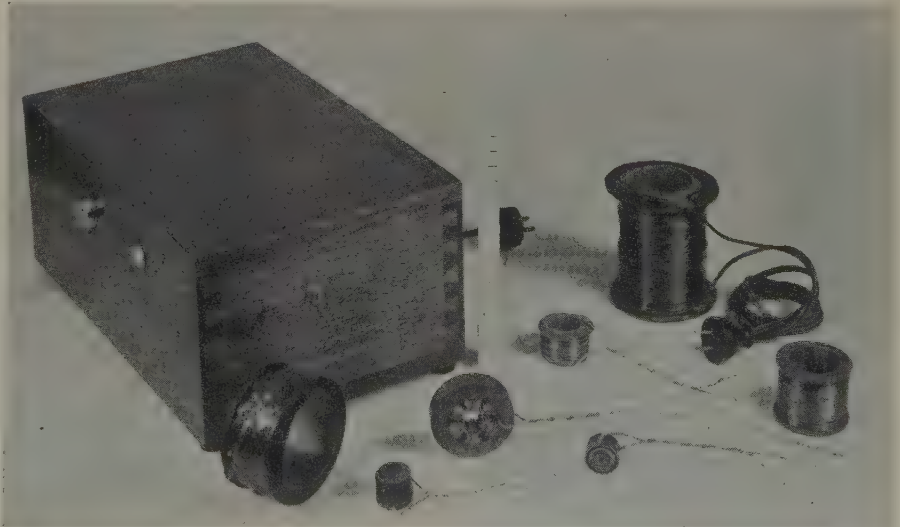
A magnetizer for permanent magnets that recently has been constructed at the National Bureau of Standards (NBS) is unusually compact, portable, and low in cost. Devised by George M. Orr of the NBS electromechanical ordnance laboratories, the magnetizer requires only a few simple and relatively inexpensive parts and weighs only 21 pounds. It normally operates from 110 volts alternating current, drawing only about 30 watts yet giving peak magnetomotive forces as high as 20,000 ampere turns.

Because of the complication, size, and expense of most magnetizing equipment, the "charging" (magnetizing) of permanent magnets has been largely confined to production lines and to a few well-equipped laboratories. Two methods are in general use at present. In one of these, a current pulse of the order of 50,000 amperes and a duration of a few microseconds is passed through a single turn of heavy copper strap that circles the magnet. Equipment for this pulse method is relatively expensive, often bulky, and not always satisfactory. In another method, often used when 110-volt d-c power is available, a coil of several thousand turns wound on a soft-iron yoke is connected across the line for a few seconds; the permanent magnet to be charged is placed between the pole pieces of the iron yoke. With this method, disconnection of the highly inductive load may present a problem, and flux density is limited by magnetic saturation of the iron yoke and by heating of the coil.

The Bureau's device is a form of "flash" magnetizer in which a large capacitor is quickly discharged through the magnetizing coil. Although flash magnetizing may not be fully effective for large magnets (the short duration of the magnetizing pulse does not always permit the magnetizing flux to reach full value below the surface of the magnet), it is often quite satisfactory for smaller ones.

In the newly constructed unit, a 6,500-microfarad capacitor bank is charged to about 125 volts by a selenium rectifier from the a-c line voltage. The 400-milliampere rectifier is connected in series with the secondary of a 1 : 1 isolation transformer in the primary leads of which are connected a 2-ampere fuse and switch. Energy stored in the capacitor is transferred to the magnetizing coil by a heavy-duty 24-volt 70-ampere motor-starting relay in series with a 100-ohm 50-watt resistor. The relay coil is actuated by a push switch which is in series with a 50-ohm 20-watt resistor. Since the relay gets its operating power from the capacitor bank, it opens shortly before the capacitor voltage has fallen to zero. Because the relay contacts thus open at a time when the current through them is low, high current-interrupting capability is not required.

The unit was built at the Bureau at a low cost, using mostly war surplus parts. Capacitors rated at 650 microfarads, 80 volts, direct current were obtained inexpensively; after a



The easy portability of the NBS magnetizer is readily apparent. Inside the box are the isolation transformer, selenium rectifier, capacitor bank, and relay. Magnetizing coils of several designs, tailored to different applications, are shown in front of the box. The large coil at the upper right is an a-c demagnetizing coil

forming period they operated satisfactorily at 125 volts. Power consumption varies between 70 watts (capacitor discharged) and 10 watts (capacitor charged); at the normal rate of magnet charging—one pulse every 15 seconds—the average line power drain is no more than 30 watts. Because of this low power requirement, the unit easily could be designed to operate from batteries for portable use.

Several magnetizing coils have been constructed for the magnetizer of designs that varied with the shape of the object to be magnetized. Although iron yokes are necessary for multipolar or radial magnetizing, simple layer-wound solenoids have been found quite satisfactory for general use. Optimum coils have from 150 to 200 turns, a d-c resistance in the range of 0.3 to 1.0 ohm, and an inside diameter no larger than necessary to accommodate the magnet to be charged. In typical operation with such a coil, the peak current has an amplitude of the order of 150 amperes and a duration of roughly 2 milliseconds.

Balanced Hangar Door Can Be Opened in 30 Seconds

A balanced hangar door which can be opened in 30 seconds or less has been developed by the Luria Engineering Company.

The balanced door represents a new approach to alert hangar door design and the initial 16 of this type of door are now being produced at the company's steel fabricating plant.

The balanced door, developed after months of experimentation, conforms to specifications as established by the United States Air Force. Its opening time of 30 seconds or less makes it possible for a jet fighter interceptor aircraft to start its motors within the hangar, taxi out, and be airborne in 1 to 2 minutes.

The door, which weighs 5 tons, is electrically operated but has an emergency manual crank that, in the event of power failure, will open it within 90 seconds.

The characteristics of the jet fighter interceptor aircraft are such that almost instant flight is possible. However, unlike other types of aircraft, the jet fighter interceptor's take-off under alert conditions is directly from the alert hangar. There is no time to pull the aircraft out on the apron with a tractor before starting. The engines must be started within the hangar, and to do this both the front and rear door must be open, so that when starting the motors and taxiing out of the hangar, hot gas shooting out of the exhaust tube will pass out of the rear door. Because every second is precious when jet fighter interceptors go into action, it was necessary to develop a door that would open in the shortest practical time.

Close-up from rear showing electrically operated mechanism for balanced alert hangar door

The door consists of a single leaf 64 feet wide and 23 feet high and is pivoted horizontally. It has an all-steel frame covered by corrugated steel sheets and is insulated with blanket glass fiber. It includes an access door for personnel.

The door's action is that of a balanced wheel rotating on its axle. The trunnions at each end of the door are mounted on structural steel pedestals anchored to separate foundations. Thus the door and its assembly are supported independently of the hangar structure.

The door may be locked at any point in its travel and has positive-type bumpers to insure limit of travel in each direction. This type of mounting precludes all possibility of the door being affected by air blast or high winds.

Printed Circuit Components Mass-Produced by Photoetching

More compact and efficient radios, television receivers, and communications equipment are made possible with the announcement recently of printed-circuit electronic inductors mass-produced for general use. In such components, printed circuitry replaces conventional wire windings with uniformly made printed coils, according to the Tube Department of the RCA Victor Division, Radio Corporation of America (RCA).

These components—six 40-megacycle intermediate-frequency transformers, coils, and traps—are produced by a special photoetching process which makes possible virtually limitless production of identical electronic circuits from a single photographic negative.

Conventional inductors depend upon coils of hand-wound or machine-wound copper wire to provide the desired inductance values; the exact values are determined largely by the number of turns of wire, its spacing, and the diameter of the coil form. With the printed-circuit method, both the copper wire and the wire-winding operations are eliminated. Inductances are provided by flat inductors having rectangular windings which are printed photographically on copper-clad plastic strips.

Although these RCA printed-circuit components are intended for application in home television receivers, the same photoetching process can be used to print circuits for components used in a wide range of radio and communications equipment.

The new components are intermediate-frequency types designed for television sets utilizing intercarrier-sound systems and incorporating picture intermediate-frequency and sound intermediate-frequency carriers of 45.75 megacycles and 41.25 megacycles, respectively. They include: first picture intermediate-frequency grid-circuit coil and trap (*RCA-209K1*); first picture intermediate-frequency plate-circuit coil (*RCA-210K1*); second picture intermediate-frequency grid-circuit coil (*RCA-211K1*); first and second picture intermediate-frequency filter traps (*RCA-212K1*); second picture intermediate-frequency transformer (*RCA-213K1*); and the third picture intermediate-frequency transformer (*RCA-214K1*).

The RCA Tube Department has been producing printed-circuit components on a "custom order" basis for some time. The RCA photoetching process, which closely resembles the photoengraving technique used in the printing industry, is now being used for the mass production of printed-circuit components for general use.

So precise that it will reproduce faithfully a circuit pattern having a line width of as little as 1/100 of an inch, the process assures the uniformity of any quantity of "copy" circuits produced by the master circuit on the photographic plate.

The photographic printing of electronic circuits presages unprecedented accuracy in the production and assembly of components and provides precision control of such vital factors as the coefficient of coupling. Further, the printed-circuit technique points the way to more economical and streamlined production of components, makes possible circuit arrangements impossible under conventional wire-winding techniques, indicates appreciable simplification in component design, and facilitates rapid and inexpensive circuit changes since only a new negative is required.

Printed-circuit components themselves, by nature of their radical design and high uniformity, make possible simplification of equipment design, reduction in the number of required parts, and a simplification of equipment servicing and alignment.

Simplification of servicing and alignment are illustrated by the new RCA components, which are housed within tiny metal shield cans measured only 7/8 inch square and $2^1/_4$ inches high. Alignment adjustments are furnished by special screw disks accessible from one side of each component. This arrangement enables the serviceman to make all alignment adjustments from the top of the chassis.

The production of a printed-circuit component begins with a photograph of the pattern of the required circuit. A contact print of the negative is then made on a copper-clad plastic strip which has been coated with a light-sensitive material. Following this operation, the strip is developed and placed in an etching solution. The unexposed parts of the copper are eaten away, leaving an accurate, sharply defined reproduction of the desired copper circuit. After the strip has undergone additional processing, it is inserted in a metal case.

NEMA Forms New Section on Conduits and Metallic Tubing

Within the framework of the National Electrical Manufacturers Association (NEMA) a Rigid Steel Conduit and Electrical Metallic Tubing Section has been formed recently.

Among the various functions of the new

section will be the promotion of products manufactured by the members and the dissemination of educational material and practical sales and installation training courses in accordance with the National Electrical Code. The section believes that as organized, it best can serve an ever-increasing demand for concerted training programs made by technical schools, colleges, military personnel, younger architects, and apprentice electricians.

Members presently comprising the section are ten of the leading rigid steel conduit and electrical metallic tubing manufacturers; Clayton-Mark and Company, Evanston, Ill.; Clifton Conduit Company, Inc., Jersey City, N. J.; Columbia Cable and Electric Corporation, Brooklyn, N. Y.; General Electric Company, New Kensington, Pa.; National Electric Products Corporation, Pittsburgh, Pa.; Nikoh Tube Company, Chicago, Ill.; Pittsburgh Standard Conduit Company, Pittsburgh, Pa.; Rome Cable Corporation, Rome, N. Y.; The Steelduct Company, Youngstown, Ohio; Triangle Conduit and Cable Company, Inc., New Brunswick, N. J.

Twelve More Firms Added to Dow-Edison Nuclear Power Study

The Atomic Energy Commission (AEC) has approved the addition of 12 companies as associates with the Dow Chemical Company and the Detroit Edison Company in a joint study with the AEC of the possibility of developing a nuclear reactor to produce power.

The Dow-Detroit companies will continue to be the primary participants with the AEC but will utilize qualified personnel from the additional companies, as well as personnel from other companies already associated with its project, as dictated by the needs of the project.

The 12 additional companies are: Consolidated Gas Electric Light and Power Company of Baltimore, the Hartford Electric Light Company, Niagara Mohawk Power Corporation, Potomac Electric Power Company, Rochester Gas and Electric Corporation, the Southern Company, Allis-Chalmers Manufacturing Company, Bendix Aviation Corporation, Ford Motor Company, United Engineers and Constructors, Inc., Atlantic City Electric Company, and Gibbs and Cox, Inc.

These additions bring the total number of companies associated with the Dow-Detroit project to 25. Nuclear Development Associates, Inc., and the Babcock and Wilcox Company have been affiliated with the project since its inception in May of 1951. In October of 1952, 11 other companies affiliated with the study. These were: The Cincinnati Gas and Electric Company, the Cleveland Electric Illuminating Company, Consolidated Edison Company of New York, Inc., Consumers Power Company, General Public Utilities Corporation, New England Electric System, Philadelphia Electric Company, Public Service Electric and Gas Company of New Jersey, the Toledo Edison Company, Vitro Corporation of America, and the Wisconsin Electric Power Company.

This composite of industrial concerns and utility companies will carry on the research and development program approved by the Commission in April 1952. This program is a jointly financed continuation of the first year's work with emphasis on development directly applicable to the Dow-Detroit power reactor concepts.

The investigations proposed by Dow-Detroit are in keeping with the AEC's own power reactor program and will intensify the improvement of reactors along the lines selected. Much of the work by the two companies, estimated at about $1,000,000 in direct costs for calendar year 1953, will be carried on in their own facilities. Research demanding the special facilities of the AEC National Laboratories, however, will be carried out under the direction of AEC personnel.

The associated companies will provide security-cleared personnel qualified to help carry on the Dow-Detroit work. In most instances, the men assigned to the project will have had previous experience in some phase of atomic energy. Each company will assign one or more men on essentially a full-time basis and these men will function as regular employees of either Dow Chemical or Detroit Edison. This highly trained manpower will be utilized only as required. To add management experience to the project, security clearances will be granted to a limited number of executives.

Other companies which can make a contribution to development work on this project may become associated with it. The AEC has reserved the right to designate or approve additional associated companies. Should more companies than can be accommodated desire to join the Dow-Detroit Edison project, the Commission would consider their affiliation with other existing study groups or the creation of new groups.

Infrared Top Heating Units Introduced in Electric Ranges

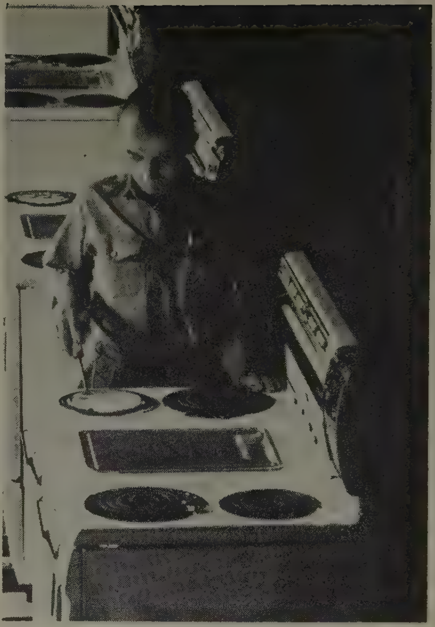
An infrared lamp in a top heating unit now is incorporated in electric kitchen ranges being manufactured on a full-scale assembly-line production basis.

The gold-lined 1,550-watt lamp is the product of 3 years of intensive co-operative research carried out by engineers of Sylvania Electric Products Inc., Corning Glass Works, and range design experts.

The lamp is the heart of the InfraRay unit which consists of the infrared bulb mounted in a metal reflector and covered by a red glass cover. Both the bulb envelope and the covering plate are made of Vycor brand glass, which withstands extreme temperature changes without cracking.

A new development in electric cooking, the InfraRay unit gives instantaneous heat at the flick of a switch and can be regulated for many different cooking temperatures. Heating is by radiation. Instead of conducting heat to a pan as electric coils do, the bulb radiates heat to the cooking utensil through the glass lid which blocks useless light rays but permits infrared rays to pass through.

The arrangement of the filaments in the lamp and the shape of the gold-lined reflector assure completely even heating across the top of the unit. Since the principle of heat by radiation is employed, pans are heated evenly although their bottom surfaces are battered or warped.



Infrared heating units on electric range get final tests on the production line

The InfraRay unit comes up to cooking temperature faster than any other heating electric unit on the market. Refrigerated butter starts to melt in 15 seconds, bacon starts to fry in 30 seconds, eggs are cooked within 2 minutes after the switch is pushed, and frozen vegetables are steaming within 3 minutes.

The InfraRay unit currently is being installed as the left front unit of a Kenmore range which is marketed exclusively by Sears, Roebuck and Company. It is hoped that production can be stepped up shortly to make the lamp available to other range manufacturers and industrial users.

Both the glass envelope of the lamp and the transluscent red glass cover plate will withstand temperatures up to approximately 2,700 degrees Fahrenheit. In tests conducted by Sylvania laboratories, lead was melted on the heated units without damage to the glass. Ice water poured over a fully heated bulb does not crack the glass. As now being marketed, the lamp is guaranteed for 1 year. Life tests have indicated that it will give service for many years under normal household use. Replacement costs of the unit are approximately the same as for standard conductor units which have a similar life span.

The red glow of the infrared lamp varies with the temperature so that the housewife knows immediately when the unit is on and whether it is set at the desired cooking temperature. The glow also serves to give visual warning of the danger of burns for housewives and curious children.

Automatic Boiler in Engine Room Relieves Boiler Plant in Summer

A completely automatic boiler situated in the engine room will permit shutting down the present boiler plant in summer at the American La France-Foamite Corporation plant at Elmira, N. Y. This saving in fuel and labor will be accomplished by one of the small compact shop-assembled units, known as the B&W Integral-Furnace, type *FM*, manufactured by The Babcock and Wilcox Company.

The new unit will be tied in with the existing high-pressure steam system for producing process steam, during the heavy-load winter months. In the summer it will operate alone to furnish the minimum process steam required for running the plant.

As the boiler is operated by push-button start and stop, the engineer can supervise it, leaving firemen free for productive work or for supplementing maintenance crews.

Formerly a large portion of the fuel burned during the summer, averaging about 50 tons per week, was used for banking and actually served no useful purpose. The new boiler will not require banking, as it will burn only enough fuel to maintain pressure during periods of low loads. Variations in steam load also are handled by automatic controls.

The new boiler will produce 8,000 pounds of steam per hour and is oil and gas fired. Fully assembled on arrival, it will need only to be set in place on the concrete basement floor of the engine room, and hooked up ready to operate.

Another innovation at this plant will be the installation of a motor-driven air compressor to eliminate the use of a steam-driven compressor during the summer months.

Du Pont Develops Process for Manufacturing Pure Silicon

Development of a process for manufacturing pure silicon, which may lead the way to more powerful and less bulky television, radio, and other electronic and electric equipment, was announced recently by E. I. du Pont de Nemours and Company, Inc.

By this process, the company has opened up a virtually unlimited source of the material—a nonmetallic element—for transistors, which appear to be revolutionizing electronics, as well as rectifiers and probably other electric parts. Furthermore, silicon is expected to broaden the scope of these developments greatly because it works over a much wider temperature range than do other materials available.

The entire production is now coming from a small pilot unit at the Newport, Del., plant of the Du Pont Pigments Department. Output is now on a scale large enough to supply extensive research programs throughout the country.

While silicon and its compounds are well known in industry, it is the pure element developed by Du Pont laboratories that is likely to become a major factor in the field of electricity and electronics. Du Pont scientists developed a method of making pure silicon in their continuing research for new and improved pigments.

Silicon is attractive in the electronics field because of its ability to withstand higher temperatures and to handle more power than other semiconductors. Work done thus far shows promise, but the effort has not advanced enough as yet to establish the position of silicon definitely. Du Pont is continuing research on the production process.

Germanium has been used in transistors but recent tests indicate that pure silicon will compete with it in some uses and for many purposes silicon is the only known material that will work.

This is particularly true where temperatures of more than 170 degrees Fahrenheit are involved. Silicon functions up to at least 400 degrees Fahrenheit (water boils at 212 degrees), which means that it not only can withstand more surrounding heat but can handle more power than other materials. It can handle several times as much power as germanium, for example. Properties of silicon indicate that it can bring greater accuracy and precision to electronics equipment. Another potentially important factor is that silicon is one of the most common elements in the earth's crust, in contrast to germanium which is extremely rare.

In rectifiers silicon may produce similar results and for similar reasons. In this use it would compete with selenium. The ability of silicon to withstand heat and handle greater power means smaller rectifiers with more capacity.

Intensive research in microwave radio during the war led to marked improvements in rectifiers using semiconductors. Silicon of extremely high purity carefully alloyed proved to be of great importance for the rectification of microwaves in radar. Silicon of the required purity had been produced before but the physical form was unsuitable for melting and alloying without undue pickup of impurities. Du Pont research men developed a process for manufacturing it in the coarse, crystalline form required and supplied it to radar manufacturers.

Thus, silicon played a key role in the war but afterwards there appeared to be little or no use for it until the recent, broadening research by others brought about the development of transistors and indications of other potential fields for semiconductors. The inherent physical and electrical properties of the material indicated that it would prove valuable in that development.

The pure silicon, as made by Du Pont, is a brittle, gray, sparkling element with crystalline appearance. Its specific gravity is 2.4, which makes it a little lighter than aluminum.

Military Service Will Cut Number of Engineers Available

The national enrollment of freshman engineering students for the current year is one of the largest in the history of engineering education. Yet when these students graduate in 1956, only half of them will be available for United States industries because of Reserve Officers Training Corps (ROTC) and Selective Service.

According to data supplied by the United States Office of Education, the 1952 enrollment of new students in engineering schools amounts to 51,631 and becomes the third largest class ever to enter the engineering schools. Assuming normal progression of the class, the resulting number of graduates in 1956 will be approximately 29,000. From this group, 12,400 are in ROTC.

These figures show that even though engineering classes are on the increase, ROTC enrollments are increasing also. This makes for a dim picture considering that industrial and governmental civilian needs are estimated at 30,000 engineers per year for the current decade. Added to this is the fact that there is still an estimated unfilled need for about 40,000 engineers.

"This is true," said Dr. John W. Graham, Assistant Dean of the College of Engineering and Science at Carnegie Institute of Technology, "in spite of the fact that 50,000 were graduated from engineering colleges throughout the country in 1950, 38,000 in 1951, and 30,000 in 1952."

Filling the annual need of 30,000 engineers per year for the current decade does not seem possible in the foreseeable future, he predicted. He cited figures supplied by the United States Office of Education on the estimated number of engineering graduates available for the next 4 years and the deletions which ROTC will cause in each graduating class:

Year	Total No. Of Grads.	ROTC	Balance
1953	24,000	6,800	17,200
1954	19,000	7,800	11,200
1955	22,000	12,000	10,000
1956	29,000	12,400	16,600

One of the reasons for the rising trend in ROTC enrollment, he said, is due to the Korean War. The junior and senior enrollments are low because in 1949 and 1950, as incoming freshmen, students did not seem to feel the seriousness of the Korean War. The impact of the war, however, is clearly illustrated now in the rising percentages of ROTC students in the sophomore and freshmen classes.

He added that the policy of Selective Service to defer college students from military service has caused criticism from many who may not understand the American manpower problem and the need for properly trained engineers and scientists. It should be noted that this policy provides postponement of service, not exemption from it.

Cornell University Laboratory Studies Vacuum Tube Failure

Vacuum tube failure can knock out radios, radar sets, and other electronic equipment. When the breakdowns occur in military use, the consequences are particularly serious.

The failure problem is getting close attention at Cornell University, where a team of electrical engineers is studying hundreds of burned-out and otherwise defective tubes sent from military installations the world over.

The investigation, started in June of 1951, is being conducted for the three services through the Army Signal Corps. It is expected to lead to the production of more reliable tubes. Professor Walter R. Jones heads the project.

The defective tubes arrive at Cornell carefully wrapped. Each tube is given a series of electrical and visual tests to determine the exact nature of the failure.

Information obtained from tests is correlated with a history telling where the tube came from, how it was used, and how long it performed before giving out. From this come recommendations for changes in circuits using the tubes, in operating procedures, and in the design and manufacture of the tubes themselves.

So far, several thousand tubes have reached the laboratory in Cornell's School of Electrical Engineering. Most of the testing apparatus was specially designed for the project by Professor Jones and his associates.

In addition to the military specimens, production-line rejects from various manufacturers also are undergoing study. Eventually, it is hoped, Cornell can establish a "tube library" to which manufacturers under government contract can turn to draw carefully calibrated tubes from which to build and test their products.

Air-Borne Tape Recorder Logs Flight Happenings

A compact fire- and crashproof air-borne tape recorder designed to log everything that happens during an airplane or missile flight has been announced by North American Aviation, Inc.

Using miniature electronic parts, the small recorder called NADAR, from North American Data Air-borne Recorder, originally was designed for use on United States Air Force guided missiles to report on altitude, speed, and general conduct of the vehicle in flight.

Carried by commercial, military, or private airplanes, the air-borne tape can record important information during a flight as long as 10 hours. The tape can be run for another 10 hours nonstop with the previous information being erased as the new information is recorded. More than 500 hours running time can be racked up on the recorder before it needs a service check.

Locked in a sealed, crashproof case, a 1,200-foot magnetic tape carries the log of a complete trip, including conversation in the cockpit, communications from the ground, data on pressure, altitude, time elapse, vertical acceleration, air speed, and direction. A quick check of the tape following an unexpected incident during flight would give engineers a full report of everything that happened in the airplane from take-off to the time of termination.

An 18-pound unit that fits snugly into wing roots or luggage compartments, the recorder is composed of many tiny parts designed and developed in the company's Electro-Mechanical Department for guidance mechanisms of missiles. Much smaller than recording instruments with comparable capabilities, the air-borne recorder is about the size of a portable typewriter.

30-Ton Door to Atomic Chamber Can Be Opened Easily by Hand

The touch of a hand moves a 30-ton door which has been installed at Yale University. The unusual door, 4 feet thick, provides the only entrance to the 20- by 40-foot inner chamber in Yale's new underground atomic laboratory, where a 20,000,000-volt linear accelerator is scheduled to begin operation late this summer.

Up until now, such massive doors into atomic chambers have been motor driven, but Yale engineers developed this one for reasons of simplicity, economy, and safety. They particularly cite the safety angle, since a power failure could not lock a worker in the chamber during a dangerous period.

Construction on the underground laboratory which will house the accelerator began late last summer after Yale had signed a contract with the Atomic Energy Commission, and was completed recently.

President A. Whitney Griswold of Yale, in announcing the project, said the new machine "will inaugurate a whole new research program" in the field of nuclear physics which will be "of the utmost importance to the Yale Physics Department and of great possible significance to the national defense program."

The present laboratory, which has been built into a hillside on the north-central portion of Pierson-Sage Square, is the first unit of a large physics building program planned at Yale.

The new 20,000,000-volt accelerator will replace an 8,000,000-volt machine designed and built some time ago.

The new linear accelerator will be operated as a pulse neutron source for measuring the absorption and scattering of various materials for neutrons in the high-energy range. Such measurements are of vital importance for the design of future nuclear reactors. The new machine is expected to create pulsed atomic beams having an electron current from 5 to 10 times higher than beams produced by any similar accelerator now in existence.

At this stage of construction, the 30-ton door has attracted considerable attention from construction engineers. The massive door and its sister, a second door about 50 feet down a narrow concrete hall, are viewed as a step forward in such construction. The second door is $2^1/_2$ feet thick and weighs 18 tons. It, too, moves easily by hand.

Both doors hang on giant tapered roller-bearing hinges anchored in the 6-foot reinforced concrete wall of the atomic chamber.

Steel casings for the doors were cast and put into place before concrete was poured into them.

Despite their tremendous weight they move smoothly and without sound. Once in motion they also can be stopped readily by hand. They are hung with such precision that they fit tightly into the thick door-wall of the blasting and measurement chambers of the laboratory.

First Major Overhaul of Panama Canal Begun

The first major overhaul of the Panama Canal since it was built 40 years ago has begun with a quarter-million-dollar order for new motor controls for the locks, received by Federal Electric Products Company.

Replacement of motor controls is part of the first phase of a 10-year plan to overhaul the Canal to enable it to handle more ships. The first phase of the project, to be completed by 1956, will cost an estimated $1,500,000.

Prototypes of the eight types of controls already have been built and delivery of the 398 units began in May and will continue through August at the rate of about 30 units a week. All component parts of the complex mechanisms have been produced, and assembly is now under way.

The new motor controls will replace those now in operation without interrupting Canal service, according to Panama Canal Company officials. Together with repair of the lock culverts, they will shorten the time required to fill and empty lock chambers, stepping up traffic through the highly overburdened Canal.

The 50-mile canal across the isthmus of Panama was opened on August 15, 1914, and this is the first major overhaul since that time. Traffic has increased steadily, and shutdowns for repairs have increased. Necessary overhaul today reduces the Canal's operating efficiency during 5 months out of every 30, according to the board of the Panama Canal Company. It is expected that completion of the 2-phased plan will enable the Canal to handle expected increases in traffic over the next 40 or 50 years.

Operation of locks and accessory equipment is accomplished by 398 electric motors, operating on standard 240-volt 25-cycle alternating current. Six double sets of locks act as stairsteps in lifting ships over the Continental Divide, and each set of locks is operated from a control tower fitted with a large control board which is, in effect, a miniature of the locks themselves.

Water to operate the locks comes from Madden and Gatun Lakes, midway on the isthmus. Roughly 26 million gallons of water are poured out to sea in moving one ship through a set of locks. Flow of water is controlled by a series of valves, ducts, and culverts, which in turn are opened and closed by electric motors controlled from the towers.

The motors range in horsepower from $7^1/_2$ to 70. The new controls for these electric motors consist of reversing combination motor starters with circuit breaker disconnects, and combination reduced-voltage motor starters with unfused disconnect switches, of both reversible and nonreversible types. Overload relays will provide positive protection for the Canal's specially designed motors.

Unique manufacturing requirements for this electric distribution equipment are necessitated by the specifications for tropical use. All wire insulation and other parts subject to deterioration in tropical atmospheric conditions have to be protected against "attack by insects, especially cockroaches and termites," and fungusproofed with special shellac.

Pulverized Coal Converted to Synthesis Gas in One Step

A new process whereby pulverized coal is converted in one step to synthesis gas, a mixture of carbon monoxide and hydrogen which is the base of more than 100 of the world's most important chemicals, was explained before the American Gas Association recently.

Speaking before the Production and Chemical Conference of the association, Paul Grossman of the Research and Development Center of The Babcock and Wilcox Company said that the new process produced synthesis gas directly from pulverized coal in one operation, while the previous method was to convert the coal to coke and then, in additional steps, convert the coke to synthesis gas. He also pointed out that the new process would produce the gas much more economically than the old method by permitting the use of lower grade coals, and also would lend itself to operation in widely diversified locations instead of only near beds of high-grade coal.

The company's 30 years' experience in utilizing pulverized coal firing for large industrial boilers, Mr. Grossman said, was an important factor in the success of this development. The first pilot plant for using the new gasifying process was built by Babcock and Wilcox for the Bureau of Mines and went into operation at Morgantown, W. Va., in the summer of 1951. It burned about 500 pounds of coal per hour and produced 330,000 cubic feet of carbon monoxide and hydrogen gas per day.

A larger size, semiscale plant was built next for the Du Pont Company and was placed in operation at their Belle, W. Va., works in the fall of 1951. This plant converted 3,000 pounds of coal per hour into gas, producing over 2,000,000 cubic feet per day. As a result of these early experiences, Mr. Grossman revealed that Du Pont has placed an order for a full-scale plant which is scheduled to go into operation some time next year. Mr. Grossman said that he could not reveal the exact capacity of the new Du Pont plant, but revealed that it would be the largest single unit in the world for producing synthesis gas by either the old or the new method. He showed drawings of a typical full-scale plant which converted 17 tons of coal per hour into synthesis gas and would produce about 25,000,000 cubic feet of this gas per day. The gas from this plant would be sufficient to supply the fuel needs of about 3,000 average homes.

To produce synthesis gas by this method, Mr. Grossman explained, pulverized coal, oxygen, and superheated steam are sprayed through a burner nozzle into a refractory lined furnace. The molten slag and ash from the burning coal and oxygen drop to the bottom of the furnace and the gases rise and are drawn off for further processing into chemicals. The plant also utilizes the heat to produce steam for other purposes.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Nomograph for Coil Calculations

To the Editor:

In reference to the article by A. C. Hudson, "Design Chart for a Single-Layer Air-Core Transformer" (*EE, Mar '53, pp 248–9*), I have prepared a nomograph for coil calculations including a chart for determining inductance-dimension data of single-layer solenoids based on the Nagaoka formula, which eliminates the need of calculation applicable especially to transmitting coils. This nomograph appeared in the January 1937 issue of *Electronics*, pages 27–8.

C. P. NACHOD (AM '07)

(Nachod and United States Signal Company, Inc., Louisville, Ky.)

D-C Motor as Capacitor

To the Editor:

In view of the interest that has been aroused by A. Boyajian's article on "The D-C Motor as a Capacitor" (*EE, Feb '53, pp 154–5*) and his letter to the editor (*EE, May '53, pp 474–5*), it is possible to push the bibliography back beyond Rüdenberg's 1923 edition of "Elektrische Schaltvorgange." B. A. Behrend in his book, "The Induction Motor," McGraw-Hill Book Company, 1921, devotes pages 189–97 to a description and outline of the theory and calculation. Behrend refers to United States Patent Number *644,554*, February 27, 1900, by Maurice LeBlanc, which shows an arrangement similar to a large D'Arsonval galvanometer which is fed by the low-frequency current from the secondary. It was called a "recuperator." Professor Gisbert Kapp of Birmingham University reinvented the LeBlanc scheme and called it a "vibrator." His work is described in the *Electrician* (London, England), May 17 and 24, 1912, "On Phase Advances for Nonsynchronous Machines." Also United States Patents Number *1,236,716*, August 14, 1917, and Number *1,258,577*, March 5, 1918, on page 194, Behrend shows a 3-armature vibrator for a 1,500-horsepower induction motor, for 2,200 volts, 3 phase, 60 cycles, 20 poles, which was built by the Westinghouse Electric Corporation. He includes eight references, dated from 1897 to 1914.

A. F. PUCHSTEIN (F '51)

(The Jeffrey Manufacturing Company, Columbus, Ohio)

Electrostatic Safety

To the Editor:

As a member of the National Fire Protection Association (NFPA) Committee on Hospital Operating Rooms, I have read with more than usual care Robin Beach's interesting article, "Electrostatic Safety for Hospital Operating Rooms" (*EE, Apr '53, pp 329–34*). We appreciate the amount of work on which the article is evidently based and, because of the complexity of the phenomena involved, we can understand that this independent study well could lead to recommendations for the specification and testing of conductive floors which are at variance with those of the NFPA committee.[1] The practical field measurement of such floors is indeed difficult to specify. However, the recommendations of the NFPA committee were not lightly arrived at. I would like to give some of the reasons for them, so that the differences between our recommendations and Mr. Beach's can be evaluated properly.

The NFPA recommendations are based on two fundamental principles. The first one governs the safe upper limit of resistance and was first explicitly stated in print by Silsbee[2] as "...the conductance must be so great that even at a voltage so low that no spark can jump, the charges will be conducted away as fast as they are produced." The same principle also was pointed out to the writer by Paul Guest of the United States Bureau of Mines a number of years ago.

The second is that the resistance of a nonlinear resistor should be measured under conditions which simulate as closely as possible those under which it is expected to function.

Actual measurements of the safe upper limit of resistance have been made by Mr. Guest[3] who shows that for conditions approximating those in hospital operating rooms a resistance of 50 megohms or less is sufficient. A few independent tests at the National Bureau of Standards, based on the first principle,[4] seem to place the upper limit at perhaps 20 to 30 megohms when human motions generate charges. The difference is hardly significant.

This, however, is the actual upper limit between the objects concerned. In determining the upper limit to be specified for tests of one component in the conductive path between these objects, such as the floor on which the objects move or rest, the second principle must be invoked also. Most types of conductive floors are semiconductors or electrolytic conductors and exhibit such vagaries as high negative voltage coefficients of resistance,[4] large contact resistances, polarity effects, and the like. The NFPA test method, intended for routine tests of installed floors, specifies that the resistance be measured between two 5-pound electrodes having resilient contact surfaces 5 square inches in diameter, with the electrodes 3 feet apart on the floor. A d-c ohmmeter having a nominal open-circuit voltage of 500 volts and a short-circuit current of 2.5 to 10 milliamperes is specified. (This incidentally fixes the internal resistance within limits that are as close as practical at the present time.) The electrodes simulate reasonably well the most common types of contacting object such as conductive rubber shoe soles and leg tips. For such resilient electrodes, the measured resistance is not greatly dependent on the load. Tests on typical floors show negligible changes when the electrode weight is increased from 5 to 150 pounds. The testing voltage is about the minimum at which a true jump spark will occur[2] (375 volts in air) or at which ignition will occur (about 600 volts for hydrocarbon-oxygen mixtures[5]). In addition, quite a number of instruments of this voltage are commercially available, an important practical consideration. The specified upper limit of 1 megohm under these conditions is entirely reasonable, as a number of tests have shown that the resistance between objects having hard-surfaced contacts with the floor, such as metal gliders or leg tips, may be 10 or 20 times the value obtained with the test electrodes, or about the actual safe upper limit.

Since people do not walk with conductive jelly on their shoes, the second principle also indicates that such paste or jelly should not be used in the routine testing of installed floors. The actual internal resistance and the high contact resistance of conductive floors can be determined best by 4-terminal measurements.[6] Quite a number of such measurements have been made on laboratory samples of flooring at this Bureau.

The use of conductive footgear and a conductive floor greatly increases the shock hazard. Griffin[7] considers that a minimum resistance of 100,000 ohms is necessary to make this hazard negligible and points out that for most types of flooring it is difficult to insure that this minimum will be maintained under all conditions. It seemed reasonable and preferable to the committee, therefore, to minimize the shock and electrical ignition hazards by specifying an ungrounded distribution system. The present committee recommendations make this hazard negligible without imposing unduly restrictive limits on the floor.

Thus these and other differences between the NFPA recommendations and Mr. Beach's can be, I think, readily resolved. Of most importance is Mr. Beach's affirmation of the hazard from static electricity in hospital operating rooms and his endorsement of the use of a conductive floor, together with conductive shoes or their equivalent, as the most effective means of controlling it.

F. L. HERMACH (M '50)

(Electrical Instruments Section, Electricity Division, National Bureau of Standards, Washington, D. C.)

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1. Recommended Safe Practice for Operating Hospital Rooms. *NFPA 56*, National Fire Protection Association, Boston, Mass., 1952.

2. Static Electricity, **F. B. Silsbee.** *Circular C438*, National Bureau of Standards, Washington, D. C.

3. Static Electricity in Hospital Operating Suites. *Report of Investigations 4833*, United States Bureau of Mines, Washington, D. C., 1952.

4. Hazards From Static Electricity. *Technical News Bulletin*, National Bureau of Standards, Washington, D. C., volume 36, June 1952, page 81.

5. Reference 3, page 61.

6. Combustible Anesthetics and Operating Room Explosions. National Fire Protection Association, Boston, Mass., 1941.

7. Low-Cost Conductive Flooring for Hospitals, **N. L. Griffin.** *Electrical Engineering*, volume 68, December 1949, pages 1085–90.

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

AERODYNAMICS OF PROPULSION. By Dietrich Küchemann and Johanna Weber. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., 1953. 340 pages, 9¹/₄ by 6¹/₄ inches, bound. $9. Dealing chiefly with jet propulsion, this book treats the aerodynamics of propulsion as distinct from the older airfoil theory which is concerned with the production of lifting forces. The first two chapters cover the general thermodynamic and flow aspects of the basic processes of propulsion. Succeeding chapters deal practically with air intakes, fairings, the ducted propeller, the ram-jet engine, the turbojet engine, the installation of jet engines, and certain specialized problems. Cooling is covered in detail, and there is a brief discussion of aerodynamic propulsion in nature.

AIRCRAFT STRUCTURAL MECHANICS. By Franz R. Steinbacher and George Gerard. Pitman Publishing Corporation, 2 West 45th Street, New York, N. Y., 1952. 346 pages, 9¹/₄ by 6¹/₄ inches, bound. $6.50. This text has been prepared with two factors in mind: the prerequisites provided by the average engineering curriculum, and the time commonly available for instruction in aircraft structures. The included material is divided roughly into three equal parts: the first is concerned with classical applied mechanics topics of an advanced nature which are essential in the analysis of the airframe; the second treats the calculation of shear lows due to various loadings on the structure; the last part deals with the buckling of various elements used in the airframe.

ALTERNATING CURRENT WAVEFORMS. By Philip Kemp. Chapman and Hall Ltd., London, England, second edition, 1952. 406 pages, 8³/₄ by 5³/₄ inches, bound. 50s. One of a series of monographs intended to give the electrical engineer a modern orientation of important subjects commonly inadequately treated in textbooks or of which the literature is widely scattered. This volume discusses nonsinusoidal waves, presenting the facts necessary for a proper understanding of the subject. The properties of complex waves, the effect of iron and of other circuit conditions, harmonics in polyphase systems and transformers, and harmonic analysis are treated.

CONSTRUCTION AND APPLICATIONS OF CONFORMAL MAPS. (Applied Mathematics Series Number 18) Edited by E. F. Beckenbach. National Bureau of Standards. (For sale by Superintendent of Documents, Government Printing office, Washington 25, D. C.) 1952. 280 pages, 10¹/₂ by 8 inches, bound. $2.25. The 32 papers presented in this symposium cover a wide range of physical applications, chiefly with relation to electric machinery, electronic apparatus, mechanics, and fluid dynamics. Several papers also serve to introduce the mathematician to the use of high-speed calculators for the approximate solutions of problems. A bibliography of numerical methods in conformal mapping is included.

THE ELEMENTS OF NUCLEAR REACTOR THEORY. By Samuel Glasstone and Milton C. Edlund. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York 3, N. Y., 1953. 416 pages, 9¹/₄ by 6¹/₄ inches, bound. $4.80. This volume presents the whole field of nuclear reactor theory and provides for the engineer the basic knowledge for an understanding of reactor technology. Based on lectures given at Oak Ridge, Tenn., the book begins with the more elementary physical concepts and processes of nuclear reactions, and then develops at length the fundamental principles involved in the calculation of the critical conditions for chain-reacting systems—including both homogeneous and heterogeneous reactors—giving detailed mathematical derivations. The book concludes with an explanation of the transport theory and the use of slowing-down kernels.

LEHRBUCH DER WICKLUNGEN ELEKTRISCHER MASCHINEN. By Rudolf Richter. Verlag und Druck G. Braun, Germany, 1952. 276 pages, 9³/₄ by 7 inches, bound. DM 32. The three major sections of this textbook on windings of electric machines cover: I. Windings with commutator; II. A-c windings (without commutator); III. Aids to the design of windings. The section on 2-layer windings has been greatly enlarged in the new edition, and new developments have been incorporated, but the size of the book has been reduced by omitting discussion of all necessary parts not directly concerned with windings.

SERVOMECHANISM ANALYSIS. By George J. Thaler and Robert G. Brown. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., first edition, 1953. 414 pages, 9¹/₄ by 6¹/₄ inches, bound. $7.50. Beginning with basic principles and other background material, the authors proceed to detail the mathematical methods for analyzing servo systems, stressing the elements of analysis as being a necessary preliminary to design. Included are discussions of transient analysis, polar transfer function, logarithmic transfer function analysis, and so forth, and two special features in line with recent developments: relay servomechanisms; and the root locus method, a means of computing transient response from the transfer function equations. Considerable space has been devoted to detailed discussion of physical systems. There is a bibliography.

SUBSTATION PRACTICE. By T. H. Carr. Chapman and Hall Ltd., London, England, second edition, 1952. 467 pages, 8³/₄ by 5³/₄ inches, bound. 55s. This companion volume to the author's "Electric Power Stations," deals thoroughly with all aspects of substation design, construction, and operation. The early chapters describe types of substations, structures and outdoor equipment, and plant layout. Switchgear, transformers, converting plant, and protective equipment are also considered. The concluding chapters discuss technical considerations and questions of organization and control. The book is intended to serve as a reference work for engineers as well as a test for students.

TABLES OF CHEBYSHEV POLYNOMIALS $Sn(x)$ AND $Cn(x)$. (Applied Mathematics Series, Number 9) National Bureau of Standards. (For sale by Superintendent of Documents, Government Printing Office, Washington 25, D. C.) 1952. 161 pages, 10¹/₂ by 8 inches, bound. $1.75. A further addition to a series providing tabulated mathematical functions which previously have been wholly unavailable or available only in fragmentary or shortened form. The present table is to ten decimals and has the usual, for this series, detailed introduction explaining the method of calculation and the specialized uses of the tabulated material.

NATIONAL ELECTRONICS CONFERENCE, PROCEEDINGS. Volume VIII. 1952. National Electronics Conference, Inc., 852 East 83d Street, Chicago 19, Ill., 1953. 835 pages, charts, diagrams, illustrations, tables, 9¹/₄ by 6¹/₄ inches, bound. $5. This conference, like its predecessors, provided a forum for the discussion of electronic research, development, and practical applications. Approximately 100 papers are presented, classified under the following headings: general papers; servomechanism theory; high-frequency electron tubes; audio; industrial measurements; magnetic amplifiers and servo applications; television; equipment and components reliability; waveguides; transistors, radio navigation, radar, and ultrahigh-frequency transmitter; circuits; components, assembly and measurements; semiconductors; memory tubes; computers; antennas; electronic instrumentation; engineering management in research work; coding and recording techniques; delay lines and high-frequency test equipment.

RADIO AND RADAR TECHNIQUE. By A. T. Starr. Pitman Publishing Corporation, 2 West 45th Street, New York, N. Y., 1953. 812 pages, charts, diagrams, tables, 9¹/₄ by 6¹/₄ inches, bound. $15. The essential information in the field of radio and electronics is condensed here into one volume covering the extensive literature of the past 20 years. This volume, chiefly concerned with methods and techniques for the electronic engineer and designer, stresses the role of noise, waveforms, microwave techniques, and fundamentals of electron tubes. Where possible, mathematical analysis is relegated to appendixes which form a considerable part of the text. Bibliographies with each chapter give several hundred references to specialized texts and original papers.

REMOTE CONTROL BY RADIO. By A. H. Bruinsma. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands (distributed in United States by Elsevier Press, Inc., 402 Lovett Boulevard, Houston 6, Tex.), 1952. 95 pages, charts, diagrams, illustrations, 8¹/₄ by 6 inches, paper. $1.50. In this small book the author covers in detail two control methods: an amplitude-modulation system with two independent channels; an impulse modulation system with eight channels, making it possible for eight signals to be transmitted simultaneously, but independently, on one carrier wave. Circuit diagrams of the transmitters and receivers, details of necessary components, and descriptions of the two model demonstration vessels are included.

TENSORS IN ELECTRICAL MACHINE THEORY. By W. J. Gibbs. Chapman and Hall Ltd., London, England, 1952. 238 pages, charts, diagrams, 8³/₄ by 5³/₄ inches, bound. 30s. The elementary aspects of the application of tensor analysis to electric machines are developed slowly and in great detail in the first half of the book. In this half geometrical terms and language are avoided except for occasional illustration. Subsequent development of the analysis requires the inclusion in the latter half of the book of a brief chapter on differential geometry, leading to the application of tensors to analytical dynamics, and thus to the treatment of rotating electric machines as combined electric and dynamical systems.

ILLUMINATION ENGINEERING. By Warren B. Boast. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., second edition, 1953. 340 pages, 9¹/₄ by 6¹/₄ inches, bound. $7. The present edition of this text follows the plan of the first edition of 1942, with a discussion of principles followed by consideration of sources of illumination and the design and testing of illumination systems. Chapters have been added on color, the interreflection method of design, ultraviolet and infrared sources and applications, and on wiring. The entire book has been critically reviewed or rewritten in the light of recent advances in the field.

MINING MACHINERY. By Thomas Bryson. Sir Isaac Pitman and Sons, Ltd., London, England, third edition, 1952. 508 pages, $8^3/_4$ by $5^3/_4$ inches, bound. 35s. Originally intended as a treatise on the generation, transmission, and utilization of power, the book now has been extended in scope to include other aspects of mine plant. The study of each branch of the subject is begun by consideration of leading principles upon which the further treatment is founded and representative machines and appliances are described and illustrated. In addition to covering steam boilers and steam engines, mechanical power transmission, d-c and a-c electric plant, compressed-air plant, coal face machinery, baulage and winding appliances, and locomotive transport, the book also discusses mine drainage and safety aspects.

PHOTOMETRY. By John W. T. Walsh. Constable and Company, Ltd., London, England. (Distributed in United States by Macmillan Company, 60 Fifth Avenue, New York 11, N. Y.) Second edition, 1953. 544 pages, $9^1/_2$ by $6^1/_2$ inches, bound. \$12.75. A comprehensive work on the techniques of light measurement including spectrophotometry, and colorimetry as a method of heterochromatic photometry. This complete revision of the 1926 edition describes fully the photoelectric-cell characteristics pertinent to photometric measurements and emphasizes the widespread use of photoelectric methods. It discusses the CIE (Commission Internationale de l'Éclairage) system of color specification, and the work done on a primary standard of light. Nomenclature reflects current British usage. Comprehensive bibliographies and various colorimetric and photometric tables are included.

PHYSICAL CHEMISTRY OF METALS. By Lawrence S. Darken and Robert W. Gurry. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., 1953. 535 pages, $9^1/_4$ by $6^1/_4$ inches, bound. \$8.50. The first section of this book is devoted mainly to descriptions of the solid and liquid states of alloys and metals, based on a comparatively new chemistry in which the atomic rather than the molecular structures are elaborated from fundamentals. The second section deals with classical chemical thermodynamics and the third law. The elimination of nearly all treatment of nonideal gases permits the inclusion of a more extensive treatment of pressure-temperature-composition relations in heterogeneous systems where several phases may be of variable composition, such phases being the rule rather than the exception in metallic systems. There is a final consideration of rate phenomena, particularly diffusion, with emphasis upon applications to metallurgical substances.

PRINCIPLES OF ALTERNATING-CURRENT MACHINERY. By Ralph R. Lawrence and revised by Henry E. Richards. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., fourth edition, 1953. 623 pages, $9^1/_4$ by $6^1/_4$ inches, bound. \$7.50. The principles underlying the construction and operation of the more important types of a-c machinery are fully treated. The subject matter is grouped under nine headings: static transformers; synchronous generators; synchronous motors; parallel operation of synchronous generators; polyphase induction motors; single-phase induction motors; series and repulsion motors; synchronous converters; mercury-arc rectifiers. The treatment is strongly analytical to provide a solid groundwork. An important aspect of the revision is the total rewriting of the chapter on methods of calculating performance of polyphase induction motors.

RECURRENT ELECTRICAL TRANSIENTS. By L. W. Von Tersch and A. W. Swago. Prentice-Hall, Inc., 70 Fifth Avenue, New York, N. Y., 1953. 399 pages, $8^3/_4$ by 6 inches, bound. \$10.35. The primary aim of this book is to teach a technique of analysis, while acquainting the reader with representative types of circuits in which the steady-state waveform may be considered as a series of recurring transients. Because such circuits have diverse applications, component circuits are emphasized, but little attempt is made to consider over-all systems. The analysis stresses the time-constant concept in preference to frequency considerations. Illustrative examples are included as supplementary material.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.

SMALL PARTICLE STATISTICS. By G. Herdan. Elsevier Publishing Company, 402 Lovett Boulevard, Houston, Tex., 1953. 520 pages, $9^1/_4$ by 6 inches, bound. \$12. This book discusses small particle statistics as mathematical procedures for the solution of problems met by research workers in dealing with particle sizes between 10 and 10^{-5} centimeters. Problems considered include the measurement of particle size, sampling procedures, graphical representation, and bi- and multivariate distributions, one of whose variables is particle size. Also treated are the changes in particle-size distribution through crushing, grinding, flocculation, and demulsification. A separate section is devoted to a critical review of methods of determining size distribution and surface area. Applications to a wide range of industries and techniques are indicated.

SPEECH AND HEARING IN COMMUNICATION. By Harvey Fletcher. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York 3, N. Y., 1953. 461 pages, $9^1/_4$ by $6^1/_4$ inches, bound. \$9.75. A revised and substantially rewritten edition of the author's "Speech and Hearing," published in 1929, based on the author's practical experience in the relation of speech and hearing to the design of telephone systems. Roughly half the book is devoted to a detailed analysis of the sounds of speech and to the hearing process, including a special chapter on the dynamics of the middle and inner ear. The last half summarizes studies on the perception of speech sounds by normal listeners, using any kind of system immersed in any kind of noise. Concluding chapters deal with deafened listener, hearing-aid design data, and a method for computing per cent hearing loss in compensation cases.

STRÖMUNGSMASCHINEN. By Carl Pfleiderer. Springer-Verlag, Berlin, Germany, 1952. 383 pages, $9^1/_4$ by $6^1/_2$ inches, bound. D. M. 36. An advanced treatment of gas and hydraulic turbines, centrifugal pumps, compressors, and so forth, intended to cover those principles common to all types of turbomachinery, either prime movers or driven machines. The several sections deal respectively with the following: fluid mechanics of runners; design and examples of operation of runners; characteristics of single-stage machines; clearance loss and axle thrust; guiding devices and passages; special aspects of axial runners; characteristics of single- and multistage compressors and turbines.

SYNCHROS, SELF-SYNCHRONOUS DEVICES AND ELECTRICAL SERVO-MECHANISMS. By Leonard R. Crow. Scientific Book Publishing Company, Vincennes, Ind., 1953. 222 pages, $8^3/_4$ by $5^3/_4$ inches, bound. \$4.20. The purpose of this book is to contribute a broad understanding of the fundamental principles underlying the functional operating theory as well as the effective application of synchros and allied self-synchronous electric mechanisms. Structural features are described in whatever detail is necessary for proper understanding of function and application of the many types and forms of these devices.

TELEVISION AND RADAR ENCYCLOPEDIA. Edited by W. MacLanachan. Pitman Publishing Corporation, 2 West 45th Street, New York, N. Y., 1953. 216 pages, $8^3/_4$ by $5^3/_4$ inches, bound. \$6. Designed both as a reference manual for engineers and for general use by the nonspecialist, this compilation covers term likely to be in common use in the United States an Great Britain. Brief definitions of terms and abbrevia tions and longer signed articles under the more im portant headings are listed in a single alphabet, wi numerous cross-references. An appendix includes list of symbols, tables of inductances, and other pertine data. Sketches, diagrams, and photographs are free used for illustration.

DIE WICKLUNGEN ELEKTRISCHER MAS CHINEN. By Heinrich Sequenz. Springer-Verlag Vienna, Austria, $9^3/_4$ by 7 inches, bound. Volume I Wechselstrom-Ankerwicklungen. 1950. 365 page \$9.90; Volume II: Wenderwicklungen. 1952. 33 pages, \$13.50. These first two volumes of a 4-volum set deal respectively with ordinary a-c armature winding and with commutator windings. Volume I starts wit the fundamentals of a single-layer m-phase a-c winding then deals with 2-layer windings, voltage polygons an winding factors, other methods of designing a-c armatur windings, excitation curves and magnetic flux polygon and finally rotor windings for induction motor Volume II discusses commutator windings separatel for d-c and a-c machines. Both volumes provid extensive detail and a wealth of diagrams, and literatur references are included.

PAMPHLETS

The following recently issued pamphlets may be o interest to readers of "Electrical Engineering." A inquiries should be addressed to the issuers.

Employment, Education, and Income o Engineers, 1949–50. The employment education, and income of senior member of engineering societies are described in a report prepared by the United States De partment of Labor, Bureau of Labor Statis tics, Division of Manpower and Employ ment Statistics. The report presents th major findings of a questionnaire surve carried out in 1949–50 for the Departmen of Defense by the Engineers Joint Counci in co-operation with 18 engineering societies The study covered 55,000 of the nation' senior engineers, more than half of all societ members of full professional grade. I provides information on the fields of speciali zation and fields of employment of thes engineers, their military status and educa tional background, and the type of work the performed. A special section is devoted t the engineers' income and the effect on thei earnings of educational achievement, age field of engineering employment, and typ of employer. Copies are available upo request from the Bureau of Labor Statistics United States Department of Labor, Washington 25, D. C.

Television and Education. Television ca be a valuable tool in education, whe properly used by skilled teachers, accordin to "Television and Education in the Unite States," published by the United Nation Educational Scientific and Cultural Organization. Although dealing primarily wit the United States, the report also give some information on the United Kingdo and France, where educational televisio experiments are under way. In the Unite States, 65 colleges and universities reporte they were engaged in some kind of televisio activities and 37 currently are offering course in television. 131 pages. \$1.00. Available from International Documents Service Columbia University Press, 2960 Broadway New York 27, N. Y.

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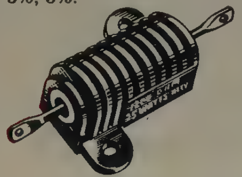

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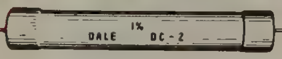

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INDUSTRIAL NOTES ....

General Electric Notes. F. H. Evans has been appointed Manager of Manufacturing for the company's Welding Department in Schenectady, N. Y. Mr. Evans is being transferred from the Meter and Instrument Department where he served as assistant to the manager of manufacturing.

The appointment of Lester H. Means as manager of employee and plant community relations for the Major Appliance Division has been announced. He will be located at division headquarters in Louisville, Ky.

Frederick J. Burnett of Schenectady, N. Y., has been appointed Supervisor of Sales and Product Planning for the Chemical Division's Alkyd Resin Products in Schenectady.

Establishment of two new sales districts, an Empire District with headquarters at Syracuse, N. Y., and a Pacific Southwest District centered at Los Angeles, Calif., was announced by the Apparatus Sales Division. William J. Woods, of Buffalo, N. Y., was named manager of the Empire District, which will include offices at Albany, Binghamton, Elmira, Jamestown, Niagara Falls, Rochester, Syracuse, and Utica, all in New York. This area formerly was covered by the New York District, which will continue to handle apparatus sales in the rest of New York, northern New Jersey, and all of Connecticut. The new Pacific Southwest District, with Edward M. Ellis of Los Angeles, as the newly appointed manager, comprises offices at Bakersfield, Los Angeles, Riverside, and San Diego, Calif., and Phoenix and Tucson, Ariz. This territory was part of the company's Pacific District, which now covers the remainder of California, a major portion of Nevada, and Hawaii.

Grady L. Roark of Schenectady, N. Y., has been appointed manager of marketing for the company's Tube Department with headquarters in Syracuse.

The General Electric Company's Welding Department located in Fitchburg, Mass., since 1946, will be transferred to York, Pa., by the end of March 1954. The transfer will enable the Welding Department and the company's Small Turbine and Supercharger Department, which will remain in Fitchburg, to expand and thereby provide room for predicted increases in the business of both departments.

Westinghouse News. Franklin P. Hinman has been advanced to the post of product manager of the headquarters plant of the Electronic Tube Division at Elmira, N. Y.

A new plant in Harmar Township near Pittsburgh, Pa., is expected to be completed this year to house the newly formed Atomic Equipment Department. Appointment of four men to key positions has been announced. They are Leo B. Dorsner, supervisor of manufacturing; Ralph M. Yearick, supervisor of production; James L. Ackerman, administrative assistant to the department manager; and Benjamin Cametti, manager of the pump engineering section.

Lawrence Radtke has been appointed staff assistant to the manager of the northeastern lamp plants. The northeastern lamp plants include the large and miniature lamp plants at Bloomfield, N. J., and a plant at Trenton, N. J.

G. L. Wilcox has been appointed vice-president of operations, and J. D. Mickle, general sales manager of the Westinghouse Electric International Company. Mr. Wilcox formerly was vice-president of sales, and before that was general sales manager for the company. Mr. Mickle, who will direct all sales activities of the company, previously was director of sales for the North and South American areas.

I. G. Fox has been appointed manager of materials for the Transformer Division at Sharon, Pa. In the newly created position, Mr. Fox will have supervision over the production control, purchasing, shipping, factory, and finished stock stores activities, and general responsibility for total inventory investment.

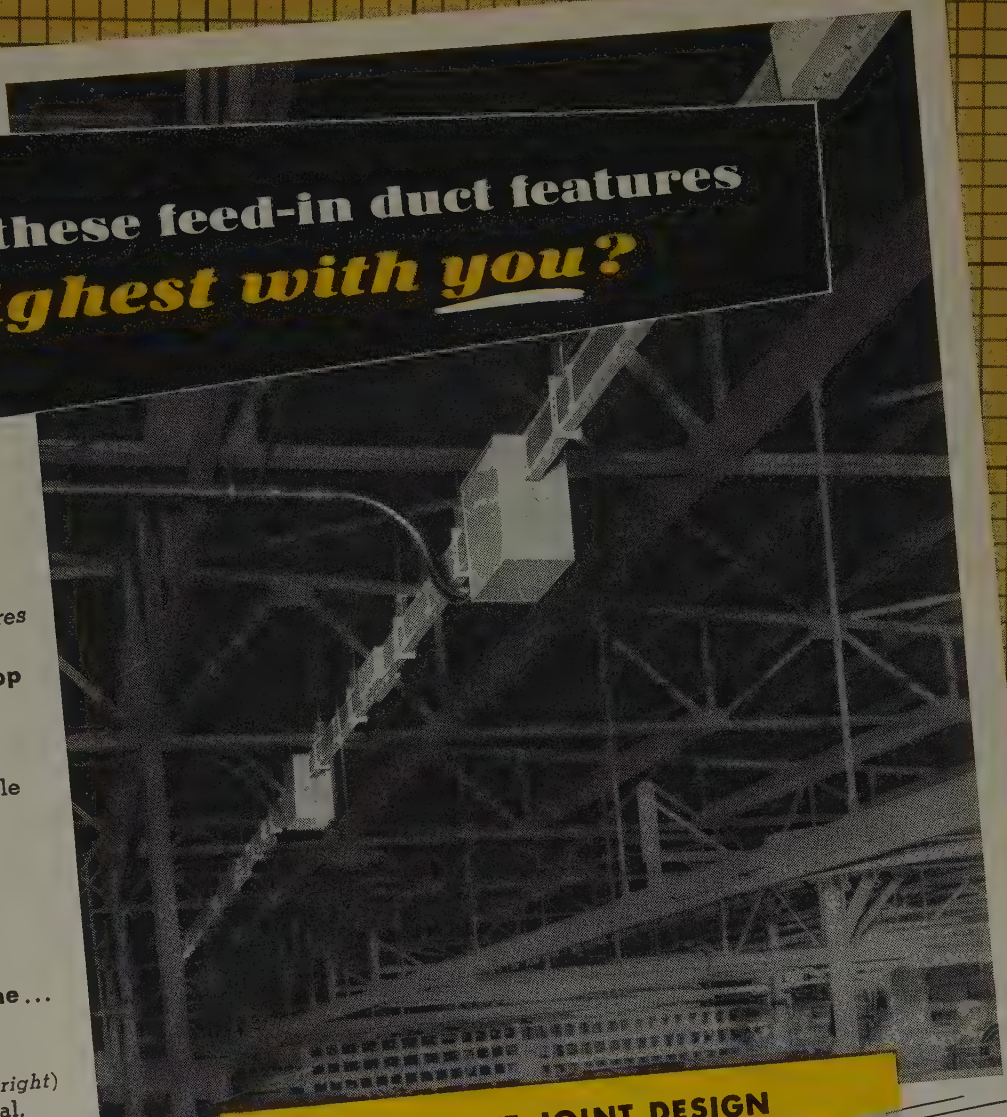
New Organization. Formation of a new organization for the purpose of sales engineering, field servicing, and technical consulting in the electrical, electronic, electromechanical, and mechanical engineering fields has been announced. The corporation, to be known as Tecon, is headed by J. Herrmann, with P. Marcus as vice-president. Mr. Herrmann was formerly associated with the Westinghouse Electric Corporation and Taylor Instrument Company; Mr. Marcus comes to Tecon from Bell Recording Company, where he held the position of chief engineer. Offices of Tecon are located at 550 Fifth Avenue, New York, N. Y.

U. S. Rubber Appointment. Harold M. Winton, training director for the mechanical goods division, has been named to the newly created post of sales development manager. Mr. Winton has been associated with United States Rubber since 1946 when he joined the sales training department of the tire division. In 1950, he was appointed director of personnel and training for the mechanical goods division, where he became responsible for development programs for training in sales and production.

Executive Vice-President Named. Herbert W. Hoover, Jr., has been named executive vice-president of the Hoover Company. Mr. Hoover, a grandson of the late W. H. Hoover, founder of the company, started working for the firm in 1933 with a job on the assembly line in the North Canton, Ohio, plant. In 20 years' time he has worked in almost every major department, ultimately winding up in sales. For several years he has supervised operations of the Hoover Home Institute, a research organization designed

(Continued on page 22A)

which of these feed-in duct features *rate highest with you?*



architects

rate these SQUARE D features particularly high:

lowest known voltage drop . . . maximum efficiency, minimum power loss

smallest cross-sectional area . . . conserves valuable installation space

contractors

give these features top billing:

reduced installation time . . . simplified components, factory prefabrication

new joint design (*lower right*) . . . all joint ends identical, connection bolts face outward

interchangeable standard fittings . . . permit horizontal or vertical riser applications

users

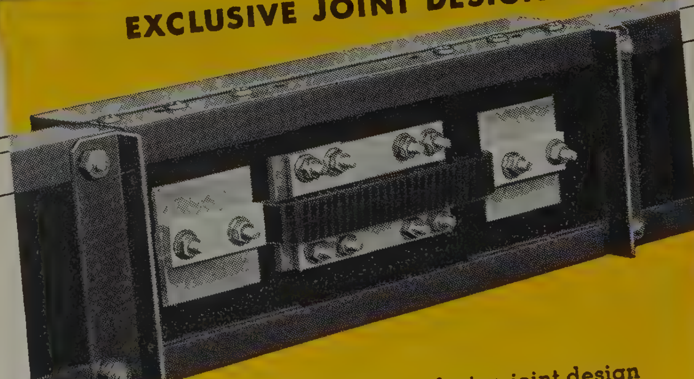
vote these SQUARE D features tops:

low cost installation and maintenance . . . most accessible connections

totally enclosed . . . permanent safety construction, excludes dust

completely reuseable . . . rearrangement with the same components

EXCLUSIVE JOINT DESIGN



SQUARE D's exclusive joint design saves installation time and reduces maintenance cost. Joint ends are identical—unnecessary to select mating ends before positioning or hanging duct sections. Outward-facing, pre-installed bolts permit rapid assembly and easy maintenance.

ASK YOUR **ELECTRICAL DISTRIBUTOR FOR SQUARE D PRODUCTS**

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- VSWR less than 1.2 at all frequencies to **3000 mc.**
- **TURRET ATTENUATOR** featuring **"Pull - Turn - Push"** action with 0, 10, 20, 30, 40, 50 DB steps.
- Accuracy ±.5 DB, no correction charts necessary.
- 50 ohm coaxial circuit. Type N Connectors.

COAXIAL LINE TERMINATION
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SINGLE ATTENUATOR PAD
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VSWR ± 1.2 to 3000 mc.
One watt c.w. power dissipation

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(*Continued from page 18A*)

to anticipate changing needs and trends in home appliances.

New Sprague Post. Appointment of William M. Allison as technical advisor has been announced by the Sprague Electric Company, North Adams, Mass. Mr. Allison has been a senior executive in the Sprague Research and Engineering Department for the past 20 years, contributing to nearly all phases of Sprague technological development in his prior posts of supervisory engineer and chief design engineer. He is the holder of a half-dozen patents pertaining to capacitors.

Rome Cable Change. The Los Angeles, Calif., office and warehouse of the Rome Cable Corporation has moved into a modern new building at 2510 South Malt Avenue, East Los Angeles. The company's factory and main office is at Rome, N. Y. It also has a plant in Torrance, Calif., where metallic tubing and conduit are produced.

Sylvania News. The elections of Don G. Mitchell as chairman of the Board of Directors and H. Ward Zimmer as president of Sylvania Electric Products Inc. were announced recently by the Board of Directors. Their headquarters are at Sylvania's executive offices in New York City. Mr. Mitchell, who has been president of Sylvania since 1946, succeeds as chairman, Max F. Balcom, a member of the Sylvania organization and predecessor companies for 35 years. Although Mr. Balcom is retiring from the chairmanship, he will continue to serve as a director and in consultative and advisory capacity.

Sylvania's 23,500-square-foot warehouse-sales office located at 5010 Kemper Avenue, 4 miles southwest of the downtown business section of St. Louis, Mo., has been formally dedicated. It is described as one of the most modern in the world for the warehousing of electric and electronic equipment.

IRC Opens Syracuse Sales Office. The International Resistance Company, Philadelphia, Pa., announces the opening of a Syracuse Sales Office on May 15, 1953, located at 112 Montgomery Street, Syracuse 2, N. Y. James G. Perkins, Jr., has been appointed General Manager; Richard Johnson, Assistant Manager; and Miss Anne Florek, Customer Service Correspondent.

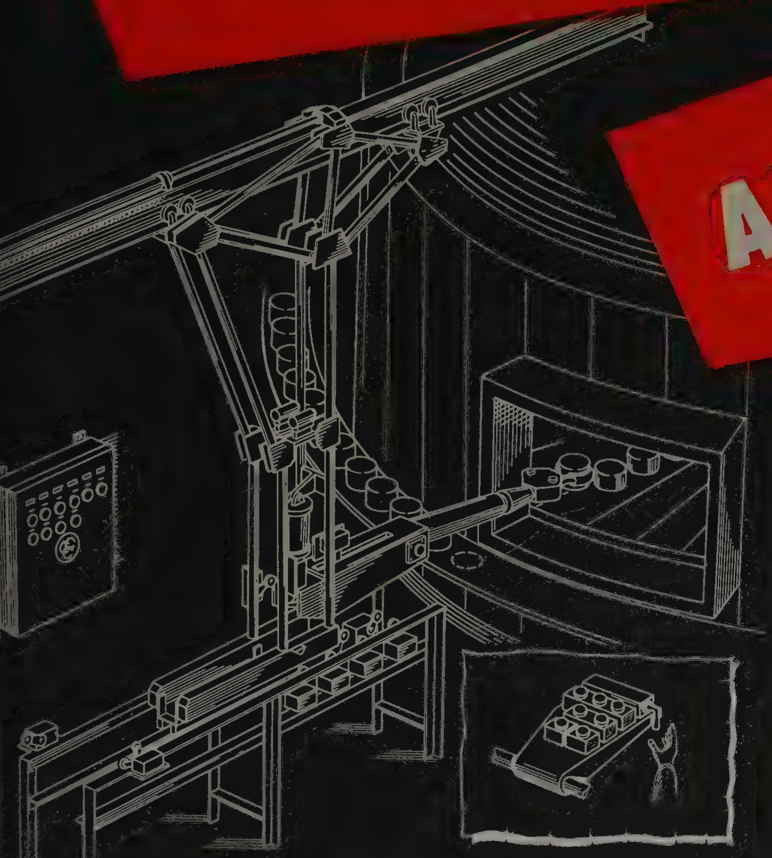
NEW PRODUCTS • •

New Lines Developed. A closed-circuit television system and the company's first line of matched high-fidelity sound-reproduction system components have been developed by RCA Engineering Products Department. The "TV Eye"

(*Continued on page 28A*)

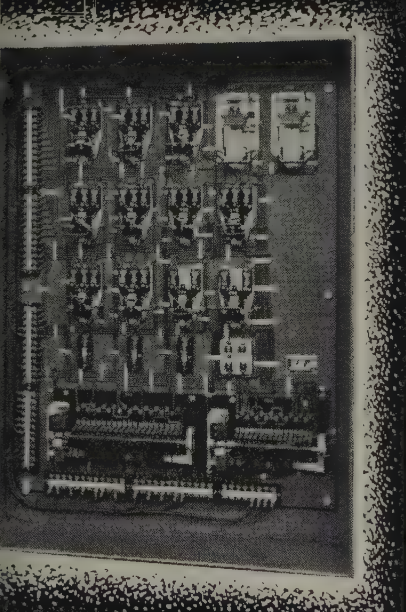
How's This For —

AUTOMATION?



This mechanical hand is called a Billet Charging Machine. It automatically loads cylindrical steel billets into a rotary furnace, one row at a time, to be heated for forging.

The machine picks up a billet from the conveyor and sets it down inside the furnace. It repeats this operation until it has lined up a full row of billets. A selector switch determines whether there shall be three or four billets to a row. The cycle is repeated when the furnace rotates to the next loading position.



Seven separate motions are required to load each billet. Thus the complete cycle involves either 21 or 28 individually controlled motions for the row.

The Billet Charger was designed by E. Homer Kendall, Consulting Engineer, of Alliance, Ohio and built by May-Fran Engineering, Inc., of Cleveland. The special automatic control panel — the brain of the machine — is Clark designed and Clark built.

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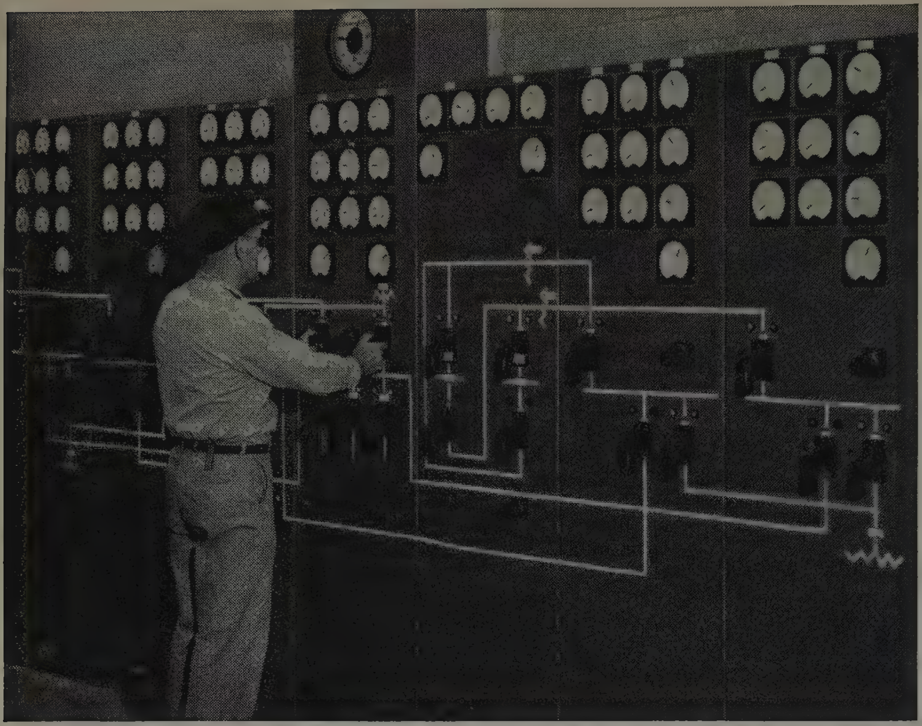

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One man at one of these new switchboards can handle a complete control room or industrial process. It's a marvel of efficiency.

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These instruments are readable from wide angles. They can be mounted high on the board—and are fully legible from underneath. Old-style instruments would be mounted lower and strung out horizontally, making for long unwieldy boards.

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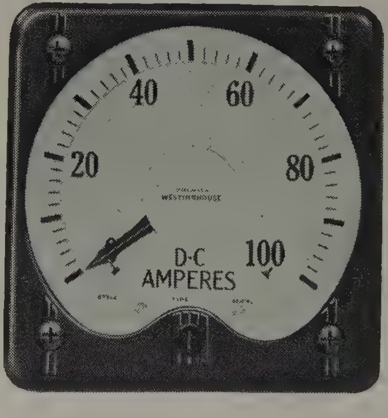
When you need *any* kind of electrical measuring instruments—call in Westinghouse. And write now for Booklet B-4695, "Getting A Full Measure". Westinghouse Electric Corporation, Box 868, Pittsburgh 30, Pa. J-40428



No shadows, no glare, no parallax interfere when you use the Full-View K-24 instruments. The climax of 65 years of intensive study, they are a triumph of optical engineering.

YOU CAN BE SURE...IF IT'S
Westinghouse

EVERYTHING YOU NEED IN METERS AND INSTRUMENTS

(*Continued from page 22A*)

closed-circuit system consists of a simplified 4-pound television camera and a compact control unit weighing only 14 pounds. The new line of high-fidelity components, the first ever offered by RCA, brings into this rapidly expanding field a company with more than half a century of achievement in the development of sound recording and reproduction equipment. Although the new components will be marketed individually to preserve the flexibility and freedom of choice demanded by most high-fidelity enthusiasts, characteristics will be carefully matched to insure maximum performance in any system comprised of them. Initial units of the "TV Eye" system are expected to be available early in September. Built around the widely acclaimed "Olson speaker," designed by Dr. H. F. Olson, director of the acoustical research laboratory of RCA's David Sarnoff Research Center at Princeton, N. J., the line will include a de luxe 3-speed automatic record changer, two amplitude-modulation–frequency-modulation tuners, 4 different high-fidelity amplifiers, 3 high-fidelity speakers (8-inch, 12-inch, and 15-inch), and separate speaker and equipment enclosures.

Pulse Transformers. A new line of miniaturized pulse transformers for blocking oscillator applications was announced by Raytheon Manufacturing Company, Waltham, Mass. These new pulse transformers, suitable for use in commercial as well as in government equipments, are available in three different styles. One style has a plug-in octal base construction, the second, a hermetically sealed *MIL-T-27* construction, and the third, an encapsulated version with a built-in solder seal for chassis mounting. Designed with a choice of several different wiring connections, these standard models will satisfy the large majority of applications of blocking oscillator circuits.

Test-Point Jack. A new test-point jack, also called terminal jack, has been developed and put on the market by Cannon Electric. Titled *45-E* Series and designed to accommodate standard 0.081-inch-diameter phone tips, the jacks are used for patch boards, high-voltage disconnects, feed-thrust, stand-offs, switching range calibration, and general laboratory use. The jacks are 15/16 inch over-all. They have nylon insulation at the rear of the fitting to afford high flashover values averaging 4,000 volts, 60 cycles rms. For additional information and dimensional data write for *TJ-1* Bulletin, Cannon Electric, 3209 Humboldt Street, Los Angeles 31, Calif.

Millivoltmeter Introduced. A single-point double-range indication millivoltmeter pyrometer, incorporating a newly designed plug-in galvanometer, has been developed by the Industrial Division of Minneapolis-Honeywell Regulator Company. The dual temperature indicator is to be more stable in operation, relatively free from the effects of vibration and

(*Continued on page 38A*)

NEW

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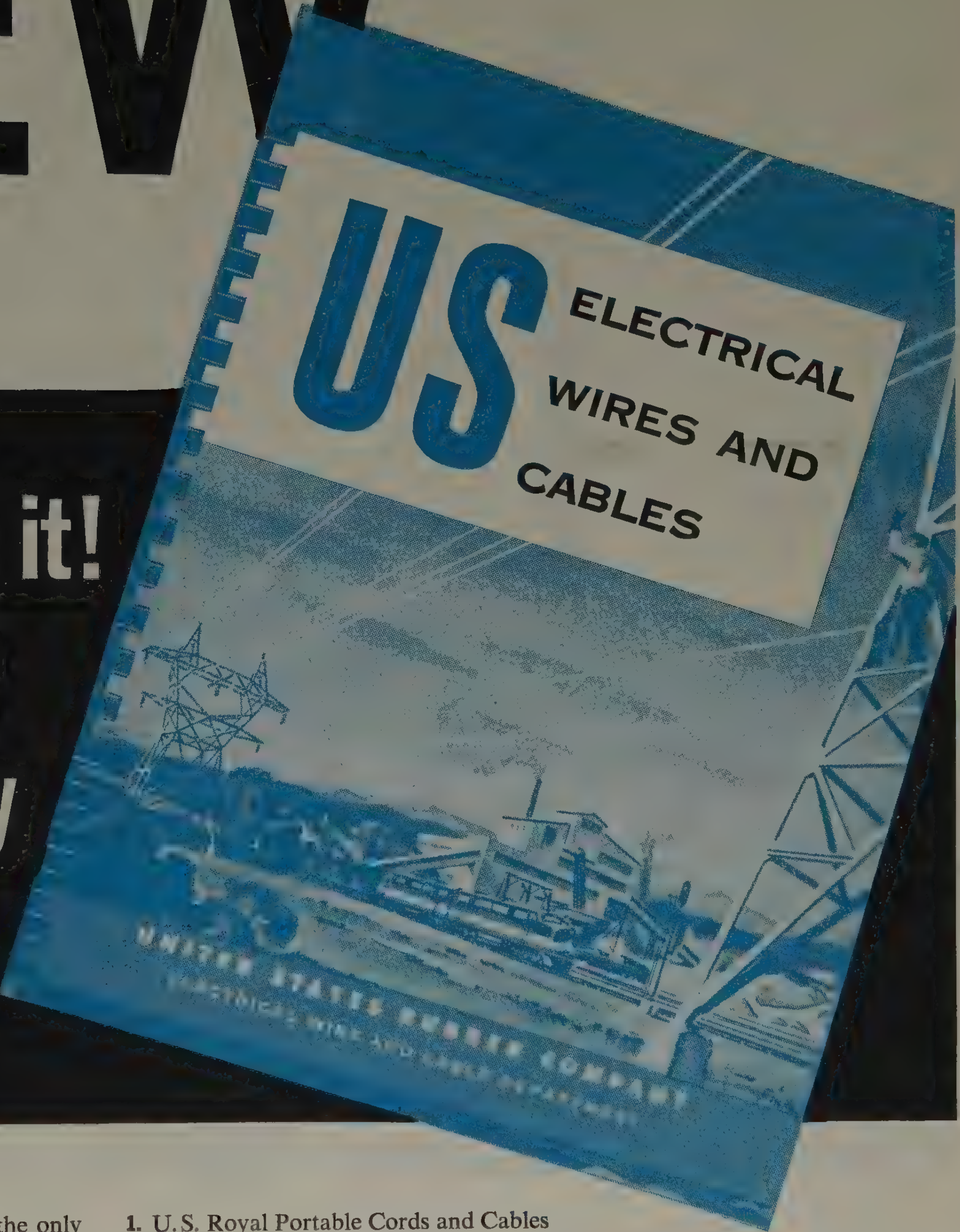
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United States Rubber Company, the only electrical wire and cable producer to grow its own natural rubber and to manufacture its own plastics and synthetic rubber, makes a complete line of electrical wires and cables for every industrial and domestic application. Just published is the 1953 "U.S." Catalog, essential for men who specify, install or maintain electrical wire and cable. Send for your free copy to address below. Here are the catalog chapter headings:

1. U.S. Royal Portable Cords and Cables
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3. U.S. Power Cables
4. U.S. Control and Signal Cables
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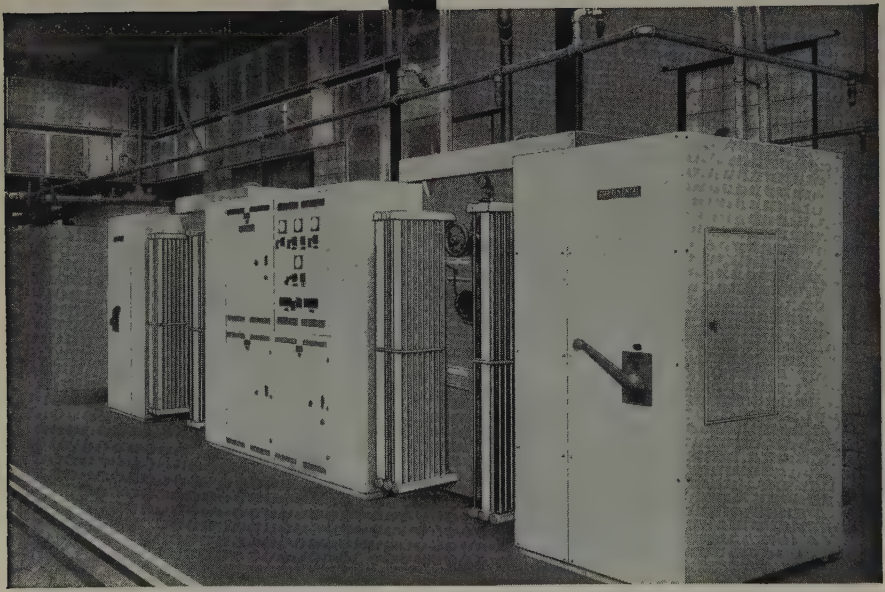
theater switchboards

wireway

● ● ● the modern, low-cost "packaged" method of supplying power. This Continental installation is a 3000 KVA Double Ended Unit. With Continental equipment, you can coordinate your complete electrical distribution system. And, Continental craftsmanship gives you top performance and appearance value.



DATA ON INSTALLATION PICTURED
High voltage sections: Load Break Air Interrupter Switches.
Transformers: Askarel Immersed, 1500 KVA, 3-Phase, 12,000-480 V.
Switchgear: 600 V., Drawout Type Air Circuit Breakers.
Bus Duct: Continental Low Impedance Feeder Bus Duct.

CONTINENTAL
ELECTRIC EQUIPMENT CO.
BOX 1055-E, CINCINNATI 1, OHIO

. . . manufacturers of
one of the most complete lines of
Electrical Distribution Equipment

Before you decide on any Electrical Distribution Equipment, be sure you have Continental's engineered proposals and delivery schedules! Your inquiries will be given prompt attention . . . and Continental's standardized equipment will get you into action . . . fast!

Send for
literature and standards

Specify Continental . . . with Confidence!

(*Continued from page 28A*)

temperature, and more easily serviced than earlier types of millivoltmeters. Two combinations of ranges, 0 to 2,400 and 0 to 3,000 degrees Fahrenheit, and 0 to 2,000 and 0 to 3,000 degrees Fahrenheit, will be offered as standard. Other combinations will be supplied on a special basis.

Mercury Lamp. To fill the size gap between 400- and 1,000-watt mercury lamps now on the market, the Westinghouse Electric Corporation has announced a 700-watt mercury lamp, the *A-H18*. Giving 35,000 lumens initially, the new lamp further widens the possible uses of mercury lighting by providing a mercury lamp which is especially well suited to medium mounting heights. The *A-H18* will have a recommended minimum mounting height of 24 feet. This means that it will find considerable use in street lighting as well as in flood and general lighting applications which demand an intermediate-size mercury lamp. Having an average rated life of 4,000 hours, it may be operated from 460-volt circuits with a simple, inexpensive choke and from other voltages with a suitable ballast which also acts as a transformer.

Axial Lead Resistor. A new axial lead precision wirewound resistor for subminiature electric and electronic equipment has been developed by the Shallcross Manufacturing Company, Collingdale, Pa. The Type *18* resistor is rated at 0.25 watt, yet it measures only 3/4 inch long by 9/32 inch in diameter. Featuring a noninductive winding and a standard tolerance of 1 per cent, the tiny resistor is available in resistance values up to 400.000 ohms. A sales drawing of the Type *16* resistor is available on letterhead request to the manufacturer.

Lightweight High-Voltage Rectifier. The new Westinghouse heavy-duty high-voltage rectifiers permit more efficient design of mobile equipment where reduced weight and space are desired. They are one-third the size of existing tubes with comparable ratings and carry peak currents of 900 milliamperes, average currents of 150 milliamperes, without overloading. The high-wattage thoriated tungsten filaments require only 3 seconds' heating. Filament terminals may be operated either up or down. For further information write Westinghouse Electric Corporation, Electronic Tube Division, Department A-111, Elmira, N. Y.

Relay Rectifier-Suppressor. A rectifier-suppressor for use with d-c relays has been developed by International Rectifier Corporation of El Segundo, Calif. The Type *D-2906* is encapsulated within a thermosetting plastic material offering complete protection in adverse environmental conditions such as moisture, fungus, salt spray, and corrosive vapors. This unit consists of two elements, one provides half-wave rectification of the a-c input and the other provides a path for the current resulting

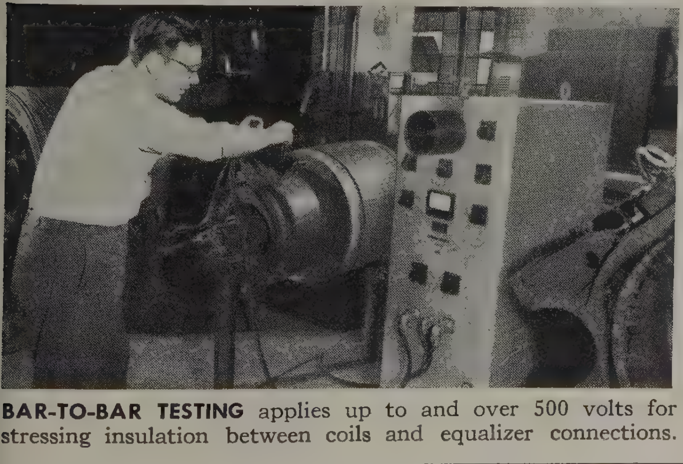
(*Continued on page 50A*)

GROUND IN ARMATURE MAY BE LOCATED TO WITHIN 1½" IN SLOT. METHOD FINDS FAULTY COILS WITHOUT TEARING APART CONNECTIONS.

Accurate location of d-c insulation defects

Pick-up coil on G-E tester locates ground on armature or stator within 1½ inches

SURGE TEST and pick-up coil will determine and locate type of fault on stator. Can also stress insulation on large a-c stators.



BAR-TO-BAR TESTING applies up to and over 500 volts for stressing insulation between coils and equalizer connections.

Addition of a new pick-up coil as standard equipment has increased the versatility of General Electric's winding insulation tester. It can now be used to locate a ground on the armature or stator within 1½ inches of its exact location in the slot.

According to customers testing railroad and coach traction motors, the G-E equipment easily does the job of three conventional testers with a greater degree of accuracy. Use of the pick-up coil makes it unnecessary to disturb any connections in locating faults on armature or stator.

Following tests can be made:

ON THE ARMATURE:

1. High-potential tests
2. Locate grounded or shorted commutator bar
3. Locate faulty equalizers under the windings directly behind the commutator
4. Locate individual grounded coil and determine whether it is top or bottom coil

ON THE STATOR:

1. High-potential test with surge test
2. Determine type of fault—ground or short
3. Surge test individual coil before or after assembly

Further information about G.E.'s winding insulation tester may be obtained from your nearest G-E Apparatus Sales Office. Or write for bulletin GEC-794 to General Electric Co., Section 687-127, Schenectady 5, N. Y.

You can put your confidence in—

GENERAL ELECTRIC

school:

THE MILLER LEXINGTON fluorescent luminaire offers these important advantages:

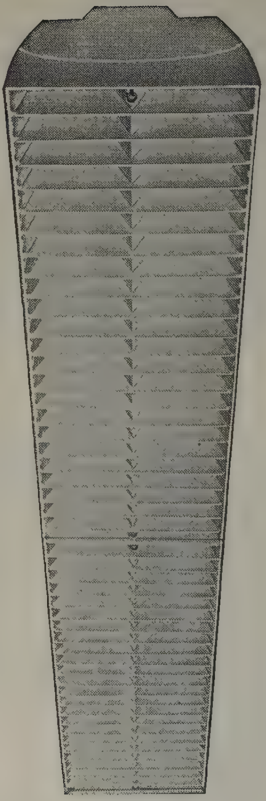
LIGHTING—highly efficient with extremely low brightness for true visual comfort.

ECONOMY—easier, quicker installation, and low maintenance — *low overall cost* (of fixtures, installation and maintenance the *true cost*). Achieved by new engineering features. More for your school lighting dollars. Write for details.

DESIGN: *Functional—clean, simple lines.*

EASY *2-way lamping—1 ladder position.*

STRENGTH: *Rigid 1-piece steel louver.*



THE **miller** COMPANY *Meriden, Connecticut*
LEADERS IN LIGHTING SINCE 1844

(*Continued from page 38A*)

from the collapse of the magnetic field of the relay coil during the nonconducting half-cycle. This arrangement provides chatter-free operation of the relay. The Type *D-2906* measures 3/4 inch in diameter and 1 inch long and is provided with 3 pigtail leads. The unit is rated 48 volts maximum input and 5 milliamperes output in 100 degrees centigrade. It is an ideal unit for operation of 30-volt d-c relays from an a-c supply.

Special-Service Motors. Two new special-service fractional-horsepower motors, for applications requiring moderately high starting torque, have been announced by the General Electric Company's Fractional Horsepower Motor Department. Rated at 1/2 and 3/4 horsepower, 1,725 rpm, the new motors can be mounted in any position, and are easily reconnectable at terminal board for 115 or 230 volts. With starting currents which conform to the National Electrical Manufacturers Association standards, the motors can be used in evaporative coolers, attic fans, milking machines, compressors, garage tools, and home workshops. They are an extension of the 1/4–1/3-horsepower *Form G* special-service motor series inaugurated by General Electric last year.

TRADE LITERATURE

Industrial Instrumentation. More than 300 technical case histories and general information articles on industrial instrumentation, covering all of the major industries, are listed in a special alphabetical index just published by the Industrial Division of Minneapolis-Honeywell Regulator Company. The index, covering editorial content in the firm's quarterly publication, "Instrumentation," from 1942 through 1952, describes instrumentation and automatic control applications in such industries as the steel, petroleum, chemical, textile, nuclear energy, plastic, ceramic and glass, food processing, meat packing, aviation, liquor, rubber, dairy, public utility, metal finishing, and research. Plant installations in some 162 industrial firms are described in the case histories ranging from the application of industrial instruments on huge catalytic cracking units to the utilization of automatic control equipment in the manufacture of plastic harmonicas or treatment of waste pickle liquor. The index can be obtained by writing to the manufacturer, Industrial Division, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Electrical Wire and Cable. The electrical wire and cable department of United States Rubber Company has published a new 76-page booklet entitled "U. S. Electrical Wires and Cables for the Chemical and Petroleum Industries." Divided into four main sections: Insulation Compounds;

(*Continued on page 52A*)

NEW
"SPECIAL RED" RECTIFIER
RCA-5690
Full-wave, vacuum type

10,000 HOURS—*Minimum Life!*

For dependable service in Industrial, Aircraft, and Military Equipment

RCA-5690 is your answer for a "long-life" rectifier designed especially for industrial and aircraft applications. The tube is conservatively rated to take a peak inverse plate voltage up to a maximum of 1120 volts, a peak plate current up to 375 ma per plate, and an average plate current up to 75 ma per plate. Operating at maximum rated voltages, RCA-5690 will withstand a continuous vibration of 2.5 g at a frequency of 25 cps for hundreds of hours—and impact accelerations of 500 g for short periods.

In this tube each rectifier unit has its own heater and cathode—with separate base terminals for each. The heaters can be operated in parallel from a 6.3-volt supply—or in series from a 12.6-volt supply. Unique tube base design provides exceptionally high resistance to leakage between base pins and minimizes arc-over at high altitudes (you can operate the RCA-5690 at full ratings up to 40,000 feet).

For rectifier applications where 10,000-hour life and extreme dependability are paramount, specify RCA-5690's—and be secure. Get technical data from RCA, Commercial Engineering, Section 39GR, Harrison, N. J. Or call your nearest RCA Field Office:

(EAST) Humboldt 5-3900
415 S. 5th St., Harrison, N. J.
(MIDWEST) Whitehall 4-2900
589 E. Illinois St., Chicago, Ill.
(WEST) Madison 9-3671
420 S. San Pedro St., Los Angeles, Cal.

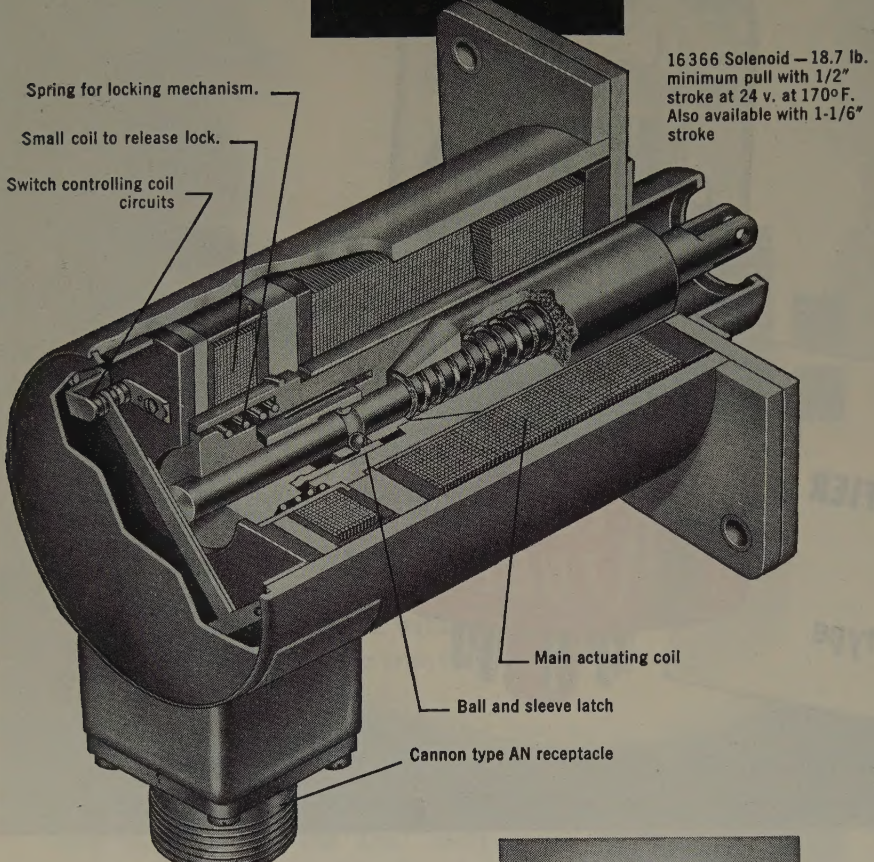
Other RCA "Special Red" Tubes
(Minimum life—10,000 hours)

RCA-5691 **High-Mu** **Twin Triode**	**RCA-5693** **Sharp-Cutoff** **Pentode**	**RCA-5692** **Medium-Mu** **Twin Triode**

RADIO CORPORATION of AMERICA
ELECTRON TUBES **HARRISON, N.J.**

Here's why those in the *know*

—demand **CANNON SOLENOIDS**


Spring for locking mechanism.
Small coil to release lock.
Switch controlling coil circuits
Main actuating coil
Ball and sleeve latch
Cannon type AN receptacle

16366 Solenoid—18.7 lb. minimum pull with 1/2" stroke at 24 v. at 170°F. Also available with 1-1/6" stroke

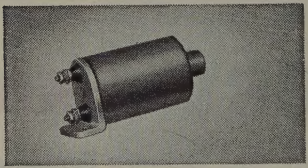
Here's a special purpose Cannon D.C. Solenoid, #16366 for aircraft. Design and safety conditions require that the armature lock in the actuated position for an indefinite time, without relying on a continuous flow of current.

The ingenious ball-and-sleeve latch locks the armature as the main coil circuit is broken through the built-in switch. When current is applied to the smaller coil, motion of the sleeve releases the main armature. Study of the drawing shows how a smooth-acting, positive lock is accomplished.

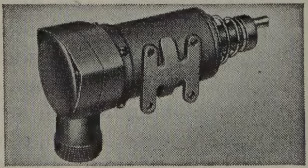
This is one of more than 60 different Cannon D.C. Solenoids built around 18 basic coils for either continuous or intermittent service. Write for Solenoid Bulletin free on request.

CANNON ELECTRIC
Since 1915
CANNON ELECTRIC COMPANY
LOS ANGELES 13, CALIFORNIA

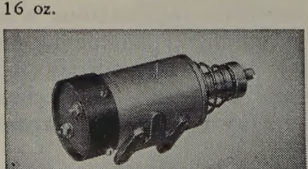
Factories in Los Angeles, Toronto, New Haven, Benton Harbor, Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. G-117, P. O. Box 75, Lincoln Heights Station, Los Angeles 31, California.



#1154 an intermittent service solenoid, 12v, D.C.—10.5 amps.—stroke 9/32", weight 13 oz.



#4440 a continuous service solenoid, 24v, D.C.—3.6 amp. (starting) .42 amp. (holding)—stroke ⅜" weight 16 oz.



# 11790 a continuous service solenoid, 24v, D.C.—3.6 amp. (starting) .42 amp. (holding)—stroke ⅜" weight 15.5 oz.

(Continued from page 50A)

Jacket Compounds; Constructions; and Technical Data, the booklet follows the successful pattern of U.S. Rubber's earlier book on the coal mining industry. The compound sections have been expanded to include butyl insulation, heat- and moisture-resistant insulations, thermoplastic types, the general-purpose neoprene jacket, and polyvinyl-chloride-type jacket. Copies may be obtained by writing the Electrical Wire and Cable Department, United States Rubber Company, 1230 Avenue of the Americas, New York 20, N. Y.

Transformer Catalogue. Listing more than 500 items, Triad Transformer's new 1953 catalogue features an expanded line of television components and industrial transformers, including toroids, pulse transformers, transistor transformers, and additional miniatures. The catalogue also contains a geophysical section. Copies of Catalogue *TR-53* may be obtained by writing to Triad Transformer Corporation, 4055 Redwood Avenue, Venice, Calif.

Scale Drawings of Gearmotors Offered. Scale drawings of the U. S. Motors Syncrogear line are now available to layout draftsmen, designers, engineers, and architects. Drawn in a simplified style, to exact scale, these drawings are designed to be inserted under a layout of a machine or other equipment and traced in the proper size and position. While saving many man hours, these drawings greatly simplify the layout man's work. Included are the following scales for each motor: 3/8 inch = 1 foot (1/32 size), 1/2 inch = 1 foot (1/24 size), 3/4 inch = 1 foot (1/16 size), 1 inch = 1 foot (1/12 size), 1 1/2 inch = 1 foot (1/8 size), and 3 inches = 1 foot (1/4 size). The drawings are on punched 8 1/2- by 11-inch paper for easy insertion into any standard 3-ring binder. The syncrogear scale drawings may be obtained by writing to U. S. Electrical Motors Inc., Terminal Annex, Box 2058, Los Angeles 54, Calif.

Slidefilms on Voltage Regulators. A new 35-millimeter full-color sound slidefilm in two parts, presenting information on the construction and use of voltage regulators in utility systems, is available from the General Electric Company. The first part, entitled "A Measure of Service," deals with the application of feeder-voltage regulation: bus, group feeder, individual feeder, and single phase versus 3 phase. The second part, "Regulation Lineup," gives details on regulator construction and design. Each film runs 20 minutes. Along with the slidefilm, sound records and a bulletin (*GED-1827*) summarizing the slidefilm, will be distributed in package form. This regulator program will be available through the company's district apparatus sales offices located throughout the country.

Electrolytic Processes. Various methods of obtaining d-c power for electrolytic

(Continued on page 54A)

NATIONAL TRADE-MARK **SA-SERIES** **MOTOR AND GENERATOR BRUSHES**

"NATIONAL" SA-series brushes were developed especially to provide a higher degree of uniformity in operation than was ever before achieved over a broad field of machines and service conditions. These brushes offer very closely controlled commutation characteristics and permit, with relatively few grades, a highly accurate, efficient brush application technique.

Many years of successful service, on all kinds of equipment and under widely divergent conditions, have *proved* the ability of this brush family to fulfill its objectives. Today, largely because of experience with the SA-series, electrical and maintenance men have come to expect . . . and they *get* . . . much more for their brush dollar all through the mill.

SA-35...has both *good commutating ability* and *long life* for a wide range of motors and generators where heavy loads and high surface speeds are combined with normal commutating conditions.

SA-3538... similar to SA-35 in load-carrying ability and commutation factor, but with distinctly different film-forming characteristics designed to prevent streaking and threading of the commutator under low average-load conditions.

SA-45... unequalled for *ridability at high speeds* and *peak commutating performance;* especially adapted to extremely severe commutating conditions on the most difficult jobs.

It pays to know your "National" brush grades . . . and to look for them under the "National" trademark on every brush you use.

HOW GOOD IS REALLY GOOD BRUSH PERFORMANCE? Write National Carbon Company

The term "National", the Three Pyramids device, and the Silver Colored Cable Strand are registered trade-marks of Union Carbide and Carbon Corporation

NATIONAL STANDARDIZED BRUSHES

BETTER– PRODUCT–PACKAGE–PRICE–FASTER

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A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, N. Y.
District Sales Offices:
Atlanta, Chicago, Dallas, Kansas City,
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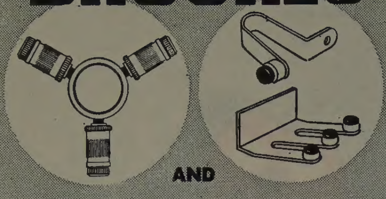
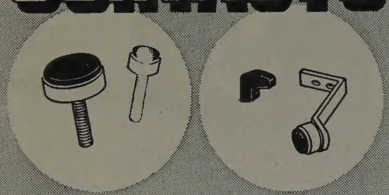
Montreal, Toronto, Winnipeg





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BRUSHES

AND

CONTACTS

... for applications requiring low electrical noise, low and constant contact drop, high current density and minimum wear.

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EXTENSIVELY USED IN

SELSYNS
ROTATING THERMOCOUPLE and STRAIN-GAGE CIRCUITS
ROTATING JOINTS
GUN-FIRE CONTROLS
DYNAMOTORS etc.

Wide range of grades available for standard and special applications.

Brush holders and coin silver slip rings available for use with Silver Graphalloy Brushes.

OTHER GRAPHALLOY PRODUCTS:

Oil-free self-lubricating Bushings and Bearings, Oil-free Piston Rings, Seal Rings, Thrust and Friction Washers, Pump Vanes.

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☐ Please send data on Graphalloy BRUSHES and CONTACTS.

☐ Send data on BUSHINGS.

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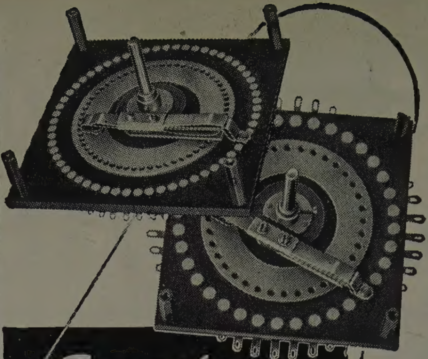

Something Special in ROTARY SWITCHES

- ☆ Single deck, single pole, 36 or 60 positions
- ☆ Easily Ganged
- ☆ Large Current Capacity
- ☆ Non-Shorting with Detent
- ☆ Isolated Shaft
- ☆ Four Point Mounting

Here's the answer to complicated range or circuit switching problems in high quality test equipment or experimental apparatus. A number of switch decks may be ganged. Both switches have a special detent which also provides the non-shorting action. The rotor arm is actually *lifted* as it moves from one contact to the next. This Shallcross design provides more usable contacts in less space than conventional non-shorting switches. Write for prices and drawings.

SHALLCROSS MANUFACTURING CO.

11 Lincoln Ave. Collingdale, Penna.

SPECIFICATIONS

Types 10061-S (60 pos.) and 10054-S (36 pos.)
Shaft Extension: 1" beyond spacers
Size: 4⅞" sq. x 1½" d.
Insulation: Phenolic. Isolated shaft.
Avge. Contact Resistance: 0.006 ohms max.

	#10061-S	#10054-S
Voltage Breakdown:	1500 v.	2500 v.
Current Capacities Carrying— Breaking—	 30 amps. 2 amps. at 110 v. a-c	 40 amps. 3 amps. at 110 v. a-c

Shallcross

(Continued from page 52A)

processes are described in a new 16-page booklet available from the Westinghouse Electric Corporation. Because electrolytic processes are widely used in the production of chemicals, aluminum, and magnesium, and some phases of steel production, all of which have varied requirements, this booklet evaluates the factors that would determine a particular choice of method. Consideration of the available methods of conversion is followed by charts to help the user select the best d-c operating voltage and a discussion of the advantages and disadvantages of private generation of power. For a copy of this booklet, *B-5466*, write the Westinghouse Electric Corporation, Box 2099, Pittsburgh 30, Pa.

Measurement Instruments. As a contribution toward the problems met in distribution, transmission, and substation engineering, Sangamo Electric Company has prepared a 20-page booklet that deals with the use of measurement instruments in obtaining continuous accurate information as to the real conditions at key points of a system. The purpose of the booklet, "Solving Distribution System Problems Through Measurements," is to explain how measurements of determining factors, which serve as a guide in solving system operating problems, can be made practically and economically. The text points out the value of lagged meters which absorb minor variations in the lagged response and provide average values that have functional worth. Measurement of ampere loading, kilowatts, reactive kilovolt-amperes, voltage data, and kilovolt-amperes are discussed. Copies are available without charge. Write to Sangamo Electric Company, Springfield, Ill.

Servomechanisms Catalogue. A 20-page illustrated catalogue describes a new line of miniaturized hysteresis synchronous, control, and damped control instrument motors designed and manufactured by Servomechanisms, Inc., Westbury, N. Y. These new motors offer the designer various frame sizes, speeds, and input voltages for military and commercial applications. Catalogue is available on request either by reader's service cards or standard company letterhead.

Heating Applications Film. Typical electric heating applications are graphically illustrated in a new color movie titled, "This Amazing Heat." Designed as an educational aid for management, engineering, production, and maintenance men, the film shows resistance-type electric heating units at work in a wide range of industrial processes. A number of case histories are used to show important benefits of using the basic strip, tubular, radiant, and cartridge units, individually or in packaged combinations. Applications cover many different industries. The film is 16 millimeter, sound and color, with a running time of 24 minutes. It is suitable for showing at power company meetings and other industrial gatherings. Further information and scheduling can be obtained by writing to Edwin L. Wiegand Company, 7500 Thomas Boulevard, Pittsburgh 8, Pa.